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CONVENTION ISSUE

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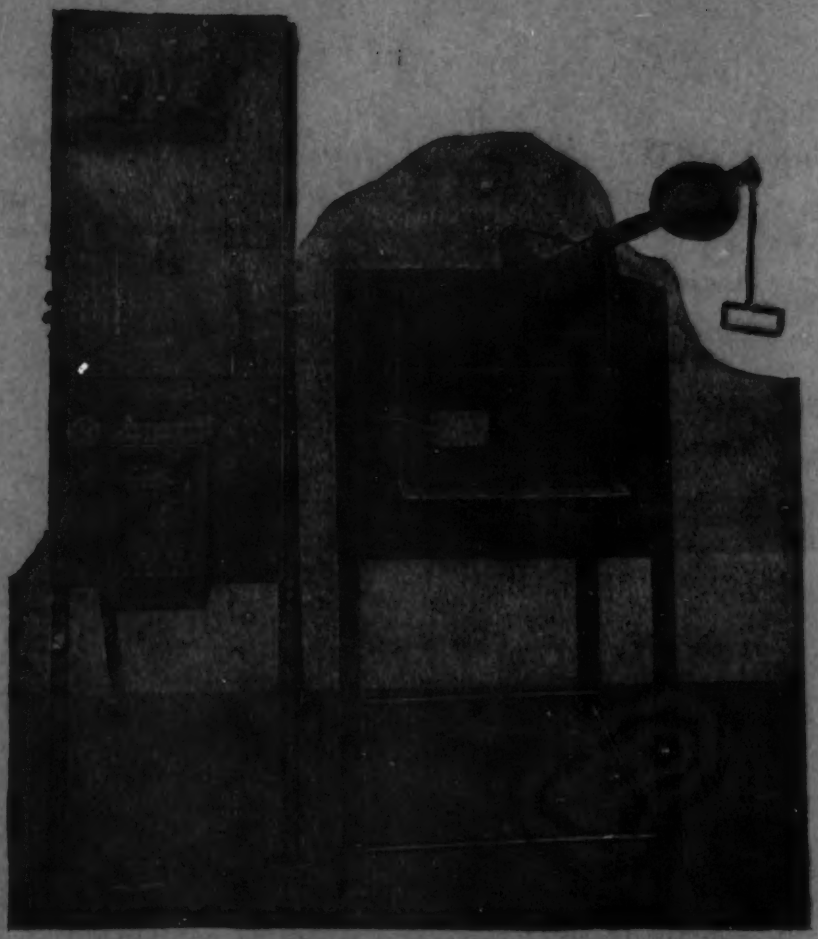

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A type of G-E equipment, distinctive in design, is the Semi-Cylindrical Heat Treating Furnace.

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The G-E Semi-Cylindrical Heat Treating Furnace is used for heat treating tools, for heat treating processes in the laboratory, and for many other heat treating processes up to 2000° F.

This G-E Furnace will be exhibited at the Convention in Indianapolis, Sept. 19-24—See it at Space 35, Manufacturers Building, Indiana State Fair Grounds.

General Electric Company

General Office **Schenectady, N. Y.**

39-78

TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, September, 1921 No. 12

THE COMING CONVENTION AND EXHIBITION

ON SEPT. 19 the American Society for Steel Treating will convene in Indianapolis for its Third Annual Convention. The meeting will mark the first anniversary of the amalgamation into one great society of two societies devoted to the heat treatment of steel, the formal proceeding of which took place in Philadelphia on Sept. 14, 1920. From every standpoint, the uniting of forces has been an advantage and the Society has been able to exert an influence greater than would have been possible by two organizations having the same purpose. Executive reports to be submitted at the business session of the Convention will testify as to the truth of this statement.

During the year just passed the Society has had a well rounded growth. Today all classes of membership aggregate 3200 members, a substantial increase over one year ago. At the time of amalgamation the society consisted of 27 local chapters; at the present time it can boast of 31, a gain of four chapters. This gain is significant other than in point of numbers for the new chapters installed during the year have expanded the territorial area in which the Society exerts an influence. By reason of large active memberships, embracing representatives from practically all plants in which heat treated products are made, local chapters have been able to secure able speakers and high caliber technical papers. The most important of these have been published in TRANSACTIONS from time to time. Chapters of the Society will be found to rank top notch among other technical organizations in all engineering and industrial centers.

Thus it is with a satisfaction of work well done and a desire to accomplish more that the Society meets in its coming convention. In spite of the present business depression which is affecting all industry, present indications point to a highly successful convention. Plans have been well made both by the National Headquarters and the Indianapolis Chapter for the entertainment of members and guests while remaining in Indianapolis. The Papers Committee has secured a most complete list of technical papers as is attested to by the program printed elsewhere in this issue. For the first time simultaneous sessions are to be held, an arrangement which will permit the presentation of a greater number of papers than heretofore and will enable members to attend the sessions in which they are most interested. It is hoped that this plan of conducting meetings will encourage discussion, which is a prime purpose of every convention.

As in the past an exhibition will be held in connection with the convention. For this purpose the Manufacturers Building at the State Fair Grounds has been secured. It has sufficient floor space for booths and is

so provided with gas and power facilities that exhibitors will display their equipment in working order. Although business conditions are not such as to warrant more than conservative exhibits, the Society has been fortunate in securing a large list of exhibitors, who will have on display the latest and most efficient products and equipment used in heat treating. That these exhibitors who make the Convention of the Society possible by their patronage will be at considerable expense in presenting their products goes without saying. Thus it is hoped that members and guests will attend the exhibition frequently and by inspecting the various exhibits will show the greatest appreciation.

HOTEL RESERVATIONS ARE HEAVY

HOTELS in Indianapolis already are reporting heavy registration for the week of Sept. 19. Thus it is important that members and guests who are planning to be present should write immediately to the various hotels in order to secure their reservations.

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reservations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then present the letter when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$2.00 up " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$2.50 to $4.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 "	not over $3.50 " "
Haugh Hotel	60 "	" " " " "
Linden Hotel	250 "	" " " " "
Majestic Hotel	59 "	" " " " "
Roosevelt Hotel	187 "	" " " " "
Royal Hotel	85 "	" " " " "

FIG. 1—MANUFACTURES BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE THIRD ANNUAL EXHIBITION OF THE AMERICAN SOCIETY FOR STEEL TREATING WILL BE HELD, SEPT. 19-24

MATCH RACE FOR THE INDIANAPOLIS CONVENTION

GEORGE DESAUTELS, chairman of the Entertainment Committee for the Convention and Exhibition of the American Steel Treating Society to be held at Indianapolis, Sept. 19 to 24, has issued announcement of a match race between Frontenac and Duesenberg automobiles.

This 50-mile match race will be staged on the Speedway, Wednesday morning, Sept. 21 at 10.00 a. m. This is the first time in the history of the Speedway that consent has been given for staging a race of any kind on this track other than the Annual Race on Decoration Day.

Three or four Frontenac cars and three Duesenberg machines will be entered.

These two manufacturers of racing cars are located in Indianapolis and are great rivals, thus it will be a good race inasmuch as both firms are particularly anxious to secure the valuable trophy which will be presented to the winner.

In addition to the match race Mr. Duesenberg has agreed to stage an exhibition with his special car which has made a record of 156 miles per hour. It is also possible that Jimmie Murphy and his car in which he won the Grand Prix in France will also be in Indianapolis, and enter this race which is being arranged for the benefit of the visitors and delegates to the steel treating Convention. .

While the race probably will be the largest event and probably of greatest interest to the visitors, nevertheless, Mr. Desautels has arranged for golf tournaments, tennis tournaments, and ball games between the eastern and western delegates. Dances, smokers, vaudeville, and a continual round of enjoyment are promised for the visitors. Indianapolis has always been the most hospitable city and the steel treaters are looking forward to having the largest Convention, and the most enjoyable occasion in their history.

SPORT IN INDIANAPOLIS

GEORGE DESAUTELS, chairman of the Entertainment Committee; is planning to have an inter-city tennis tournament, and also an inter-city golf tournament. Any exhibitor, member or guest from the various

cities may enter these tournaments. Trophies will be awarded the winning tennis team, and to the best golfer. The course at Highland Golf and Country Club has been secured for the golf tournament. This course represents the sportiest and best in the United States, and it will be a treat to every golfer to try out the excellent course.

Not only will there be prizes for the individuals and teams turning in the lowest score, but there will also be prizes for the dubs. So do not permit the fact that you are no low medal artist prevent you from bringing your golf sticks along and enjoying the game. If you're going to bring your golf sticks and tennis rackets along, communicate with George Desautels, Imperial Drop Forge Co., Indianapolis.

THE LADIES

BRING them with you to Indianapolis. Then check them with the Ladies Entertainment and Recepton Committee. They will be well taken care of.

At the previous Conventions of the Society many of the visitors succeeded in persuading "Friend Wife" to go with them, and the ladies were so well taken care of, that it is now impossible for these visitors to attend the Convention unless they bring their wives.

The Ladies Entertainment Committee has arranged a most tempting program and will keep the ladies pleasantly and advantageously busy during the entire week.

The Ladies' Headquarters will be on the mezzanine floor of the Claypool Hotel, and will be open every day of the Convention with a secretary in charge.

FIG. 2—INTERIOR OF MANUFACTURES BUILDING, SHOWING A PART OF THE 76,000 SQUARE FEET OF FLOOR SPACE TO BE USED BY THE EXHIBITORS

PROGRAM FOR THE CONVENTION

AT THE time of going to press, it is impossible to list various papers which will be read upon certain days of the Convention; however, programs will be distributed at the Convention and will give complete information. The general plan for the presentation of papers has been laid out subject to slight changes, and will be about as follows:

Monday, Sept. 19—Opening Session, 2 P. M., Women's Building, State Fair Grounds, Indianapolis, Ind.

Chairman, W. R. Chapin

Address of Welcome .....
W. R. Chapin, Chairman Executive Committee, Indianapolis Chapter
Welcome to Indianapolis .....City Official
Response .....A. E. White, National President
Report of Tellers of Election.....R. T. Bayless, Chairman
Report of Secretary.....W. H. Eisenman, National Secretary
Report of Treasurer .....W. S. Bidle, National Treasurer
President's Address .....A. E. White, National President
Announcements.

Tuesday, Sept. 20

10 A. M.—Papers on Carburizing.
2 P. M.—Papers on Tool Steel.
6 P. M.—Smoker and Entertainment.

Wednesday, Sept. 21

10 A. M.—Motor Speedway.
50-Mile Match Race between Duesenberg and Frontenac Motor Cars.
2 P. M.—Room A.—Papers on Heat Treating Equipment—Room B—Papers on Alloy Steel
8 P. M.—Dance and Entertainment

Thursday, Sept. 22

10 A. M.—Room A—Program in charge of the Army and Navy—Room B—Papers on Alloy Steel
2 P. M.—Room A—Papers on Metallographic Research—Room B—Papers on Heat Treating Equipment
6 P. M.—Annual Banquet. Speakers of National Prominence

Friday, Sept. 23

10 A. M.—Research Session in charge of Dr. Harrison E. Howe, Chairman of the National Research Council, Washington, D. C.
2 P. M.—Room A—Papers on Heat Treating Problems—Room B—Papers on Shop Management

Special attention is called to the fact that owing to the large number of excellent and interesting papers, simultaneous sessions will be held on three days of the Convention so that visitors may have the opportunity of attending the sessions which are of the greatest interest.

Army and Navy Session

The Army and Navy program on Thursday morning will be especially interesting and the following general program will be presented.

The Chief of the Navy will detail an officer to present a paper on "Laying of the North Sea Barage."

General Amos A. Fries, chief of Chemical Warfare Service will have a paper presented on some subject of interest to the members.

General C. C. Williams, chief of the Ordnance Department has

asked F. C. Langenberg, metallurgist of the Watertown Arsenal to present a paper on the heat treatment at the Arsenal.

Major L. W. McIntosh, assistant to the Chief of Engineering Division, Air Service, War Department, will have a paper presented on "Heat Treating Problems in Aeronautics."

Research Session

Dr. Harrison E. Howe, chairman of the National Research Council will preside at the Research Session on Friday morning. Dr. Howe has consented to secure the speakers for that session, in which the general plan for research in heat treatment will be presented and discussed.

PAPERS TO BE PRESENTED AT THE CONVENTION

INVESTIGATION and progress in heat treating is being made every day and steel treaters should keep abreast of the times. It is but necessary to read the comprehensive list of papers given below in order to be satisfied that the topics mentioned and the men pre-

FIG. 3—WOMAN'S BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE SESSIONS OF THIRD ANNUAL CONVENTION OF THE SOCIETY WILL BE HELD

senting them will make it worth while to go hundreds of miles to hear them.

After reading this list over carefully, consult with the other executives of your firm, and undoubtedly they will agree with you that it is absolutely necessary to send representatives to the convention if you are to continue to maintain the high standard of your products.

Manufacturers realize as never before that the materials they produce are only as good as their heat treatment. It is an interesting fact that the most successful firms are those concentrating and devoting a great amount of thought and capital to the development of their heat treating plants.

Now is a time when money must be saved, expenses must be reduced, and while it may be felt that business conditions would not justify a visit to the Convention, it is only necessary to obtain but one

important idea which you may be applied to conditions in your own plant in order to be more than fully repaid for the entire expense of the trip.

A few days spent in Indianapolis will increase efficiency and save money in plant operation.

Following is a list of papers which will be presented at the various sessions of the Convention:

TOOL STEEL

C. M. BROWN, V. P. Colonial Steel Co., Pittsburgh, Pa. Paper: *"Tool Steel Specifications."*

W. G. CALKINS, Metallurgist, Detroit Twist Drill Co., Detroit, Mich Paper: *"Notes on Forged High Speed Milling Cutters."*

A. H. d'ARCAMBAL, Metallurgist, Pratt & Whitney Co., Hartford, Conn. Paper: *"Physical Tests on High Speed Steel."*

A. W. F. GREEN, Metallurgist, John Illingworth Steel Co., Philadelphia, Pa. Paper: *"Providing Properly Rolled Tool Steel for the Steel Treater."*

L. K. MARSHALL, Metallurgist, North East Electric Co., Rochester, N. Y. Paper: *"Tool Steel Manipulation."*

M. H. MEDEWEFF, Met. 5014 Weseley Ave. Howard Park, Baltimore, Md. Paper: *"Heat Treatment and Uses of High-Speed Steel."*

T. HOLLAND NELSON, Steel Works Mgr., H. Disston & Sons, Philadelphia, Pa. Paper: *"A Comparison of American and English Methods of Producing High Grade Crucible Steels."*

L. R. SEIDEL, Managing Director, New York Testing Laboratories, N. Y. City. Paper: *"Tool Steel."*

A. S. TOWNSEND, Ch. Chemist, Cleveland Twist Drill Co., Cleveland. Paper: *"The Effect of Tungsten Content on the Specific Gravity of High Speed Steel."*

METALLOGRAPHIC RESEARCH

R. L. DOWDELL, Instructor of Metallography, University of Minnesota, St. Paul, Minn. Paper: *"Reclaiming High Carbon Gears."*

J. P. GILL and L. D. BOWMAN, Metallurgist and Asst. Metallurgist, Vanadium Alloy Steel Co., Latrobe, Pa. Paper: *"Metallography of High Speed Steel."*

N. B. HOFFMAN, Metallurgist, Colonial Steel Co., Pittsburgh, Pa. Paper: *"Ghost Lines and Grain Elongation in Hot Rolled and Cold Drawn Iron Wire."*

F. C. LAU, Consulting Engr., 1437 W. Jackson Blvd., Chicago, Ill. Paper: *"The Effect of Phosphorus in Tool Steel."*

HEAT TREATMENT OF STEEL

D. N. A. BLACET, Met. Central Steel Co. Paper: *"Modern Methods of Heat Treating."*

I. H. COWDREY, Professor of Mechanical Engineering, Massachusetts Inst. Tech., Cambridge, Mass. Paper: *"The Efficiency of Annealing Overstrained Steel."*

L. S. COPE, Consulting Metallurgist, 920 Mary St., Ann Arbor, Mich. Paper: *"Coarse Grained Forgings; Their Detection and Correction."*

E. J. JANITZKY, Metallurgist, Illinois Steel Co., South Chicago, Ill. Paper: *"A Contribution to the Problem of the Influence of Mass on Heat Treatment."*

J. F. KELLER, Dept. of Forging & Heat Treating, Lewis Institute, Chicago, Ill. Paper: *"The Whys of Warping."*

C. B. LANGSTROTH, Met. A. O. Smith, Milwaukee, Wis. Paper: *"Heat Treatment of Steel."*

H. E. HAYWARD, Met. Link Belt Co., Indianapolis, Ind. Paper: *"Malleable Iron."*

S. L. HOYT & G. H. BIERMAN, Met. Engrs., National Lamp Works, Nela Park, Cleveland, O. Paper: *"On the Theory of Hardening Steel."*

T. D. LYNCH, & W. J. MERTEN, Met. Engrs. Material & Process Eng. Dept., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"Tests Showing the Effect of High Temperature on Malleable Iron."*

W. J. MERTEN, Met. Engr., Westinghouse Electric & Mfg. Co. Paper: *"A Coiling and Heat Treating Plant for Helical Springs."*

W. P. PRIESTLEY, Supt. of Hot Metal Div. U. S. N. O. P., Charleston, W. Va. Paper: *"Fracture Test on Steel to Determine its Quality."*

W. R. WARD, Metallurgist Engineer, Lyells, Va. Paper: *"Miscellaneous Heat Treating."*

W. H. WHITE, Supt. of Melting Shops, U. S. N. O. P., Charleston, W. Va. Paper: *"Heat Treatment of Steel Castings."*

J. A. GANN, Metallurgist, Dow Chemical Co., Midland, Mich. Paper: *"Dowmetal and Its Application."*

CARBURIZING

C. M. CAMPBELL, Supt. Pioneer Alloy Products Co., Cleveland, O. Paper: *"Do Alloy Carbonizing Boxes Pay?"*

H. H. HARRIS, Pres., General Alloys Co., Chicago, Ill. Paper: *"Design of Heat Treating Containers."*

V. E. HILLMAN, Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"The Efficiency of Various Mixtures for Cynaide Hardening and The Role of Nitrogen in the Process."*

W. I. McINERNY, Foreman Heat Treat. Armor Plate U. S. N. O. P., Charleston, W. Va. Paper: *"Carburizing Heavy Sections."*

H. SCHAGRIN, Ch. Chemist, U. S. N. O. P., Charleston, W. Va. Paper: *"Carburization with Wood Charcoal."*

T. G. SELLECK, V. P. GURNEY & SELLECK, 513 Peoples Gas Bldg., Chicago, Ill. Paper: *"Carburizing."*

P. W. & E. B. SHIMER, Metallurgical Engrs., Easton, Pa. Paper: *"Cyanide in Liquid Case Hardening."*

S. C. SPALDING, Metallurgist, Halcomb Steel Company Syracuse, N. Y. Paper: *"Comparison of the Rate of Penetration of Carbon Into Various Commercial Steels Used for Case Carburizing."*

MANAGEMENT

A. E. BELLIS, Pres. Bellis Heat Treating Co., New Haven, Conn. Paper: *"Shop Management."*

A. A. BLUE, Metallurgist, Duff Mfg. Co., Pittsburgh, Pa. Paper: *"A Successful Bonus System Applied to Heat Treating."*

J. WALTER BRESSLER, Philadelphia, Pa. Paper: *"System of Records for Metallurgical Departments."*

F. C. LANGENBURG, Metallurgist, Watertown Arsenal, Watertown, Mass. Paper: *(Title to be supplied later.)*

E. W. PIERCE, Metallurgist, Maxwell Motor Car Co., New Castle, Ind. Paper: *"Buying Steel on Closer Carbon Limits."*

C. F. SMART, Asst. Ch. Metallurgist. Ingalls-Shepard Div. Wyman-Gordon Co. Harvey, Ill. Paper: *"Steel Is Steel."*

W. P. WOODSIDE, Superintendent of Materials, Studebaker Corp., Detroit, Mich. Paper: *"Organizing Research To Pay Dividends."*

W. P. WOOD, Professor of Chem. Engineering, University of Michigan, Ann Arbor, Mich. Paper: *"A University Course in Metallurgical Engineering."*

H. F. WOOD and F. G. MILLARD, Ch. Metallurgist, and Supt. of Finishing Dept. Ingalls-Shepard Division, Wyman-Gordon Co., Harvey Ill. Paper: *"Production Efficiency in the Heat Treatment of Drop Forgings."*

M. H. MEDWEDEEF, Met. 5041 Weseley Ave., Howard Park, Baltimore, Md. Paper: *"Metallurgy in the Modern Shop."*

ALLOY STEEL

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper: *"Tensile Properties of Some Structural Steels at High Temperatures."*

M. A. GROSSMAN, Metallurgist, Electric Alloy Steel Co., Youngstown, O. Paper: *"The Toughness of Alloy Steels as Affected by Their Heat Treatment."*

C. M. JOHNSON, Director of Research, Park Works Crucible Steel Co. of America, Pittsburgh, Pa. Paper: *Some Alloy Steels of High Elastic Limit, Their Microstructure and Heat Treatment."*

G. C. McCORMICK, Asst. Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"A Discussion of Uranium and Allied Elements."*

H. STYRI, Chief of S. K. F. Research Laboratories, Philadelphia, Pa. Paper: *"Heat Treatment of Chrome Steel for Ball Bearings."*

J. S. VANNICK, Metallurgist, Research Laboratory, Department of Agriculture, Washington, D. C. Paper: *"Mechanical Properties of Chrome Vanadium Steels."*

PROPERTIES OF CARBON AND ALLOY STEELS

R. M. BIRD, Metallurgist, Bethlehem Steel Co., Bethlehem, Pa. Paper: *"Standardization of Methods Leading to Comparative Properties of Alloy Steels."*

A. M. COX, Asst. Metallurgist, R. D. Nuttall Co., Pittsburgh, Pa. Paper: *"Abrasive Qualities of Plain and Alloy Steel."*

H. J. FRENCH and W. G. JOHNSON, Physicist and Asst. Physicist, Bureau of Standards, Washington, D. C. Paper: *"Effect of Heat Treatment on Mechanical Properties of One Per Cent Carbon Steel."*

H. A. HOLZ, Pres. Holz & Co., New York. Paper: *"Recent Researches on the Elastic Limit."*

L. W. WILD, Pres., Wild Barfield Co., London, England. Paper: *"Influence of Heat Treatment on the Magnetic Properties of Steel."*

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper: *"Effect of Heat Treatment on Mechanical Properties of Carbon Molybdenum and Chrome Molybdenum Steels."*

HEAT TREATMENT EQUIPMENT

W. H. BRISTOL, Pres., Bristol Co., Waterbury, Conn. Paper: *"Automatic Compensation for Variation of Cold Ends of Thermo-Electric Pyrometers."*

E. D. CAMPBELL, Professor of Chemistry, University of Michigan, Ann Arbor, Mich. Paper: *"Some Brinell Hardness Measurements on Small Specimens."*

GEORGE KELLER, Sales Mgr. Brown Instrument Co., Philadelphia, Pa. Paper: (*Title to be supplied later*).

R. W. NEWCOMB, Mgr. Charles Engelhard, Inc., New York City. Paper: *"A New Type Automatic Temperature Regulator. Its Application to Heat Treating Furnaces."*

T. Y. OLSEN, V. P. Tinius Olsen Testing Machine Co., Philadelphia, Pa. Paper: *"Determinator of Stiffness of Wire on Sheet Metal."*

S. P. ROCKWELL, Metallurgist, Whitney Mfg. Co., Hartford, Conn. Paper: *"Testing of Metals for Hardness."*

C. UPTHEGROVE, Professor of Chemical Engr., University of Michigan, Ann Arbor, Mich. Paper: *"Note on the Small Brinell Machine."*

FURNACES

T. F. BAILEY, V. P. Electric Furnace Co., Alliance, O. Paper: *"Electric Furnaces for Heat Treating With Automatic Control."*

G. R. BROPHY, Metallurgical Engr., Indus. Furnace Dept. General Electric Co., Schenectady, N. Y. Paper: *"Calite; A New Heat Resisting Alloy."*

E. F. DAVIS, Sales Mgr. Celite Products Co., New York Paper: *"Construction of Furnace Doors, Lining and Bases."*

F. J. EVANS, Sales Mgr. Eng. Surface Combustion Co., Springfield, Mass. Paper: *"High Pressure Gas and Its Application to Industrial Furnaces."*

J. T. GOWER, Armstrong Cork & Insulation Co., Pittsburgh, Pa. Paper: *"Reducing Conduction and Radiation Heat Loss."*

C. L. IPSEN, Designing Engr., General Electric Co., Schenectady, N. Y. Paper: *"The Electric Furnace as it Affects Overall Costs of Heat Treated Parts."*

P. J. LAFORE, Industrial Eng., Boston Consolidated Gas Co., Boston, Mass. Paper: *"The Use of Gas Fired Furnaces for Heat Treating."*

G. M. LITTLE, Res. Engr. Div., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"An Electrically Heated Forging and Heat Treating Furnace."*

W. E. McGAHEY, Foreman, Heat Treating Large Guns, U. S. N. O. P., Charleston, W. Va. Paper: *"Heat Treatment of Large Forgings by Oil, Gas and Electricity."*

A. F. MITCHELL, Supt. Heat Treating U. S. N. O. P., Charleston, W. Va. Paper: *"A Comparison of Conditions Entering Into the Operation of Oil and Natural Gas Fired Furnaces."*

J. WEAVER SMITH, Inds. Engr., Citizens Gas Co., Indianapolis, Ind. Paper: *"Gas Accessories for the Heat Treating Room."*

R. E. TALLEY, Ch. Engr., Geo. J. Hagan Co., Pittsburgh, Pa. Paper: *"Operating Data on Electric Furnaces."*

MISCELLANEOUS TOPICS

A. E. WHITE, University of Michigan; and J. S. Vannick, Bureau of Standards. Paper: *"Note on Occurrence of Oxides and Nitrides in Boiler Tube Steel."*

F. H. HELRIGEL, Metallurgist, Motor Products Co., Detroit, Mich. Paper: *"The Heat Treatment of Copper and Brass."*

EXHIBITORS AND PRODUCTS THEY WILL EXHIBIT

THE exhibition this year will be one of the most interesting and important the Society has ever held. There will be more exhibits in operation than ever before. Over 70 firms, as listed below, producing the highest class of products will be there to meet you and greet you and not only to explain their products but to answer any questions you may have, and help you solve the difficulties in which you may be entangled.

A glance at the list of firms below will show that they represent the leaders, and they are anxious that you should examine their products. There is nothing that could be of greater value to you than to come to the Convention and Exhibition to examine at first hand the very latest in new equipment and products which should be used.

The list of exhibitors given below is not complete due to the fact that it was necessary to close the forms preparatory to going to press. The program distributed at the Convention will contain complete information.

Following is the partial list of exhibitors and their products:

Alcorn, Blockhouse Co., Philadelphia, Pa.

Armstrong Cork & Insulation Co., Pittsburgh, Pa., will exhibit:
Nonpareil insulating brick for the retention of heat in furnaces, ovens, boiler settings and other high temperature equipment.
Nonpareil high pressure covering and blocks for steam lines, feed water heaters, enameling, and japanning ovens, etc.
Nonpareil cork covering for insulation of drinking water systems in mills and factories.
Nonpareil corkboard for the insulation of cold storage and constant temperature rooms.
In Charge of Booth: J. T. Gower.

E. C. Atkins Mfg. Co., Indianapolis, Ind.

Atlas Crucible Steel Co., Dunkirk, N. Y.

Bausch & Lomb Optical Co., Rochester, N. Y., will exhibit:
Metallographic equipment and metallurgical microscopes, including two new metallographic equipments and a new form of illuminant.
In Charge of Booth: W. L. Patterson and L. I. Nixon.

Bell & Gossett Co., Chicago, Ill., will exhibit:
"Caseite"—case hardening compound.
"Bathite"—preheating bath.
Pots and Boxes.
"Cleancoat"—lead bath covering.
Selective hardening material.
In charge of Booth: E. J. Gossett.

Bethlehem Steel Co., Bethlehem, Pa., will exhibit:
One large transparency consisting of 32 photographs with appropriate colors showing representative views of all operations at a steel plant from raw materials to the finished steel product.
A new truck wheel, showing the various operations from the I-beam section to the finished wheel.
Two boards of bolts and nuts.
A number of different castings made with additions of Mayari iron, consisting of motor castings, such as pistons, cylinder heads, motorcycle cylinders; grinding plates, etc.
Several very interesting tool steel boards.
A board of drop forgings.
In Charge of Booth: W. R. Shimer, W. H. Laury, W. C. Cutler and John Moran.

Bristol **Company, Waterbury, Conn.**

The Brown Instrument Co., Philadelphia, Pa., will exhibit:

Apparatus to demonstrate what the research departments of instrument manufacturers are doing today, along the lines of developing newer and more accurate instruments. The Brown Instrument Co. plans to exhibit a number of striking samples of radical changes and improvements in instrument design and construction.

At this booth will be displayed a potentiometer, so compact that it can be carried under the arm, and yet has a scale of 96 inches long.

Automatic control showing what has been accomplished during the last year.

The heating cycle controller.

New cold junction compensated pyrometer, together with the complete line of high resistance indicating and recording pyrometers of single continuous and multiple types; indicating and recording thermometers; indicating and recording pressure gages; tachometers; and all types of instruments for temperature measuring and recording.

In Charge of Booth: G. W. Keller, C. C. McDermott, D. J. Jones, R. W. Mayer, E. R. Robinson, and S. C. Ketterer.

Bureau of Standards, Washington, D. C., will exhibit:

General equipment available for metallurgical research and testing of metals. Copies of publications considered of interest to the society will be available for examination, and typical examples of the Bureau's metallurgical work will be featured.

The exhibit as a whole will give a general idea of the scope of this work and co-operation with the metal industries.

In Charge of Booth: G. K. Burgess, H. J. French, and Miss D. E. Kingsbury.

Calorizing Co. of Pittsburgh, Pittsburgh, Pa., will exhibit:

New and used specimens of Calorizing and Calite, with some working tests of the latter material.

In Charge of Booth: B. L. Jarrett, A. V. Farr, E. L. Malone, A. A. Becker, F. D. Rice, G. H. Howe and G. R. Brophy.

Case Hardening Service Co., 2281 Scranton Road, Cleveland, O., will exhibit:

A case hardening compound, samples of Bohnite, also samples of work it has produced. These samples include gears, cam shafts, etc., which have been cut to show the cross section and polished and etched to show the depth of case. Two new devices for testing the hardness of metals which will be shown for the first time in the United States. They are both manufactured by the Rudge-Whitworth, Ltd., Birmingham, Eng.

The first, called the Auto-Punch, is a portable Brinell machine weighing only a few pounds and can be carried easily to any part of the shop or plant. The impressions made are somewhat smaller than made with the standard Brinell Machine. The instrument is manufactured for shop and production use and is so simple that any workman can operate it and yet it is accurate enough for laboratory purposes if needed.

The second instrument, known as the Quadrant Sclerometer, is used for testing the hardness of wrist pins, steering bolts, etc., and is made from two ordinary files hinged together at one end. One of these is placed in a horizontal position by the means of leveling screws. The hardness of the piece is then ascertained according to the friction generated.

In Charge of Booth: William H. Bell and C. E. Lovejoy.

Celite Products Co., New York, will exhibit:

Heat treating materials in various forms showing representative applications.

Sil-O-Cel heat insulating products, brick and powder.

Sil-O-Cel C-3 cement for forming furnace and oven doors.

Exhibit will include model furnace in operation to illustrate graphically the insulating value of Sil-O-Cel.

In Charge of Booth: E. F. Davis, H. N. Haberstroh and R. V. Massman.

Central Steel Co., Massillon, O., will exhibit:

Various steel products.

Machinability of oil hardening steels.

In Charge of Booth: F. J. Griffith, D. N. A. Blacet, L. B. Baker, C. P. Richter, and C. Beach.

Colonial Steel Co., Pittsburgh, Pa., will exhibit:
High and low carbon steel, high speed steel, annealed steel, overheated steel, burned steel, etc., to be viewed with microscope.
An auto-propector showing views pertaining to the manufacture of crucible tool steel.
In Charge of Booth: Charles M. Brown, T. H. Nimick, J. E. Barry, and N. B. Hoffman.

Crucible Steel Co. of America, Pittsburgh, Pa., will exhibit:
Complete line of steels and products manufactured from same.
In Charge of Booth: C. W. Mayer, J. W. Taylor, F. J. White, E. R. Mills, H. L. Raynor, R. Slaughter and E. E. Sharp.

Deeds Commercial Laboratories, Indianapolis, Ind., will exhibit:
Carburizing compound, demonstrating methods of use as well as the principle of quenching.
In Charge of Booth: W. C. Horner.

Deeds & Chapin Co., Indianapolis, Ind.

Driver-Harris Co., Harrison, N. J., will exhibit:
Representative Nichrome castings.
In Charge of Booth: H. D. McKinney, W. E. Blythe, C. B. Calloman, H. D. Hardegan, and H. D. Tietz.

Eaton Electric Furnace Co., Taunton, Mass.

Electric Alloy Steel Co., Youngstown, O.

Electrical Refractories Co., East Palestine, O., will exhibit:
Electrical refractories for use in resistance-type electric heating devices, including electric ranges, steel treating furnaces, enameling ovens, immersion heaters, and laboratory equipment.
In Charge of Booth: E. C. Owen.

Electric Steel Co. of Indiana, Indianapolis, Ind.

Charles Engelhard, Inc., New York, will exhibit:
Thermoelectric pyrometers.
Thermocouple parts, such as protecting tubes.
Completely assembled thermocouples.
Indicating instruments—several types.
Recording instruments—single and multiple-record.
Automatic temperature regulator.
Electric furnaces.
Impervite refractories.
In Charge of Booth: E. S. Newcomb and G. V. Nightingale.

J. B. Ford Co., Wyandotte, Mich.

William Ganschow Co., Chicago, Ill., will exhibit:
Heat treated gears of all kinds.
Spur gear speed transformer.
Bakelite and rawhide noiseless gears.
In Charge of Booth: A. F. Boissoneau.

General Alloys Co., Chicago, Ill., will exhibit:
Q—Alloys—supreme heat resisting alloys.
Will announce a new alloy at the show.
In Charge of Booth: H. H. Harris, A. D. Heath, A. L. Grinnell, P. F. McGovern, and O. A. Parine.

General Electric Co., Schenectady, N. Y.

George J. Hagan Co., Pittsburgh, Pa., will exhibit:
One 42-kilowatt electric furnace in operation. This furnace will be automatically controlled, and is representative of a complete line of electric furnaces which the George J. Hagan Co., carries in stock and manufactures in its factory at Orrville, O. This particular equipment is suitable for hardening, annealing, and carburizing steel; annealing nonferrous metals; and enameling.
One combination oil and gas-fired heating furnace in operation, with gas fuel and with automatic temperature control; also samples of oil burners for indus-

trial furnace work and steam generation, and oil burners in combination with gas fuels of various sorts for industrial furnace work.
In Charge of Booth: W. C. Buell Jr., and R. E. Talley.

Halcomb Steel Co., Syracuse, N. Y., will exhibit:
Inserted tooth and disk saws, dreadnought high speed steel.
Cold-drawn high speed steel and its products.
Punches, dies, gages, Ketos nonshrinking steel.
Automobile parts of electric alloy steels.
Bolt and nut making, Halco and Pyro hot-work steels.
Magnet steel products, stainless steel and its uses.
Wortle drawing dies, ball wire, and the making of balls, hot and cold.
In Charge of Booth: A. T. Galbraith, M. P. Spencer, J. S. Marlowe and H. J Stagg.

Heppenstall Forge & Knife Co., Pittsburgh Pa., will exhibit:
Piston Rod—showing physical properties.
Die block—giving record run while in service.
Frames containing drop forgings—showing the type of block from which they were made and average yield.
Photographs of the plant.
Shear knife—showing fracture and micrographic structure.
In Charge of Booth: J. A. Succop.

Hoskins Mfg. Co., Detroit, Mich., will exhibit:
An electric heat treating furnace, the temperature of which is automatically controlled, and which employs a new type of heating element.
Pyrometers, indicating and recording.
Nickel-chromium heat-resistant castings.
In Charge of Booth: W. D. Little, C. S. Kinneson, and C. F. Busse.

Imperial Drop Forging Co., Indianapolis, Ind.

Indianapolis Drop Forge Co., Indianapolis, Ind., will exhibit:
Drop forged dies and tools and drop forgings.
In Charge of Booth: Ferdinand Barnickol, J. C. Beyer, L. M. Fehrenbach, and Ferdinand Barnickol Jr.

Indianapolis Light & Heat Co., Indianapolis, Ind.

The Industrial Press, New York, will exhibit:
"Machinery" and its different publications.
In Charge of Booth: J. N. Wheeler, V. S. Wunder, E. K. Hammond, and H. L. Brown.

The Iron Age Publishing Co., New York, will exhibit:
The Iron Age and publications.
In Charge of Booth: F. J. Frank, C. S. Baur, F. W. Schultz, D. C. Warren, W. B. Robinson, J. Lundberg, F. S. Wayne, Emerson Findley, Don G. Heinly, B. L. Herman, E. Sinnock, C. L. Rice, A. L. Marsh, H. A. Douglass, H. E. Barr, and W. C. Sweetser.

Kinney Mfg. Co., Chicago, Ill., will exhibit:
Small motor driven positive pressure rotating plunger pump, in operation.
In Charge of Booth: A. J. Munday.

Leeds & Northrup Co., Philadelphia, Pa., will exhibit:
"Hump" method electric furnaces in operation. (Bring small tools for hardening.)
Indicating and recording pyrometers and optical pyrometer in operation.
In Charge of Booth: G. W. Tall, Jr., A. E. Tarr, Jordan Kopp, Henry Brewer, Oscar Brewer, and C. A. Martin.

Marschke Mfg. Co., Indianapolis, Ind., will exhibit:
Electrical motor-driven bench and floor-type grinders and buffers. These machines are made in the plant complete, including motors and safety devices.
In Charge of Booth: F. W. Marschke, W. A. Marschke and H. W. Marschke.

Midvale Steel & Ordnance Co.—Cambria Steel Co., Pittsburgh, Pa.

Oakley Chemical Co., New York, will exhibit:
Oakite cleaning methods and materials for removing quenching and tempering oils, thus affecting economy in labor and money. Working conditions are better, disagreeable odors and health undermining fumes are eliminated, and

methods of handling so improved that substantial savings are possible.
Oakite service men will be present in booth 60 to offer suggestions on individual problems of removing quenching and tempering oils, or other industrial cleaning problems.
In Charge of Booth: Maxwell Lakeman and C. A. Ormsby.

The Penton Publishing Co., Cleveland, O., will exhibit:
The Iron Trade Review and publications.
In Charge of Booth: F. V. Cole, John A. Penton, A. O. Backert, J. D. Pease, C. J. Stark, H. O. Taylor, L. C. Pelott, A. L. Klingeman, G. H. Manlove, E. L. Shaner, D. M. Avey, A. M. Pulaski, H. E. Diller, E. F. Ross, A. J. Hain and D. O. Taber.

Quigley Furnace Specialties Co., Inc., New York, will exhibit:
Hytempite: Demonstration of this high temperature cement for banding fire brick, blocks, tiles, and granular refractories.
Insulbrix: Refractory insulating brick for conservation and maintenance of uniform temperatures.
Carbosand: Highly refractory fire sand for furnace linings and floors, patches and repairs to linings, and for making special shapes and tile.
In Charge of Booth: W. H. Gaylord and F. W. Reisman.

W. S. Rockwell Co., New York City.

P. H. & F. M. Roots Co., Connersville, Ind., will exhibit:
One No. ½ Roots horizontal low-pressure blower, motor drive. This blower will be used for furnishing air for one half of the live exhibits at the Convention.
One No. 4 Roots Acme gas pump, arranged for drive by constant speed motor and equipped with diaphragm operated by pass valve This gas pump is of the type used for boosting the gas pressure to hardening furnaces and other industrial appliances.
The Original Roots blower. This machine is the first one manufactured by Mr. Roots in 1859.
One No. 3 Roots Acme blower arranged for single-pulley drive. This machine will not be in operation and will be for inspection only.
One No. 3½ Roots Acme blower, arranged for tight and loose-pulley drive. This machine will also not be in operation and will be for inspection only.
One No. 1 Roots Acme hand blower. This machine is of the type ordinarily furnished for use with portable forges and blacksmith fires. It will be on exhibition for examination and operation by visitors.
One No. 1 Roots horizontal low-pressure blower, pulley-drive. The case and headplates of this machine will be cut away so as to show the rotating parts. It will also be arranged to rotate slowly showing the relation and operation of the internal mechanism.

Simonds Mfg. Co., Lockport, N. Y., will exhibit:
High speed tool steel.
Carbon tool steel.
Alloy steels.
Sheets and bars.
In Charge of Booth: H. D. Need and G. R. Bird.

Smith Gas Engineering Co., Dayton, O., will exhibit:
Small model clean gas producer of sufficient capacity to operate furnaces.
In Charge of Booth: Wm. P. Duff, E. A. Adams, and R. M. Chatterton.

Spencer Turbine Co., Hartford, Conn., will exhibit:
Spencer multiturbo compressor for supplying air for oil and gas burning furnaces.
In Charge of Booth: S. E. Phillips and H. M. Grossman.

Stromberg Electric Co., Chicago, Ill., will exhibit:
Process timing and signalling instruments for controlling the time element and preventing the process from running too short or too long a time.
Sromberg No. 35 job time recorders, printing exact time of start and completion of work on any job or operation.
Stromberg in-and-out employees' recorders for payroll and time records.
Stromberg electrical time stamps for stamping exact time on all kinds of papers passing through various departments.
In Charge of Booth: Wm. P. Martin Jr.

Surface Combustion Co., New York City.

Tate-Jones & Co., Inc., Pittsburgh, Pa.

Taylor Instrument Companies, Rochester, N. Y.

Vanadium-Alloys Steel Co., Latrobe, Pa., will exhibit:
High-speed, carbon and alloy tool steels, and tools and products made from the same.
In Charge of Booth: J. P. Gill, W. R. Mau, A. G. Henry and R. D. Guisewite.

Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

Wilson-Maeulen Co., New York, will exhibit:
Rockwell hardness tester in three sizes. Also pyrometers, tapaloy, monopivot indicators and pyods.
In Charge of Booth: C. H. Wilson, Harry Goldsen and S. C. Horn.

Witherow Steel Co., Pittsburgh, Pa.

THE METALLURGY OF HIGH SPEED STEEL

By D. M. Giltinan

DEVELOPMENT of high speed steel as distinguished from carbon tool steel, has been a matter of the last 50 years. The development of the present day cutting alloys in this short space of time, as compared with the hundreds of years previous in which there was no development, calls for some explanation. This explanation lies in the fact that the manufacturing industries of the civilized world have, during the same period, demanded a means for securing increased production without the increase in cost which would accompany additional buildings and equipment. The alternative was to speed up each individual machine, and in attempting to do so, it at once became apparent that the tool steel then in use would not meet the requirements of increased speed. These requirements were:

1. The tool must possess initial hardness greater than the material cut, and also must be sufficiently hard to resist wear.

A paper presented before the Charleston Chapter. The author, D. M. Giltinan, is associated with the micro laboratory, Bureau of Research, United States Naval Ordnance Plant, Charleston, W. Va.

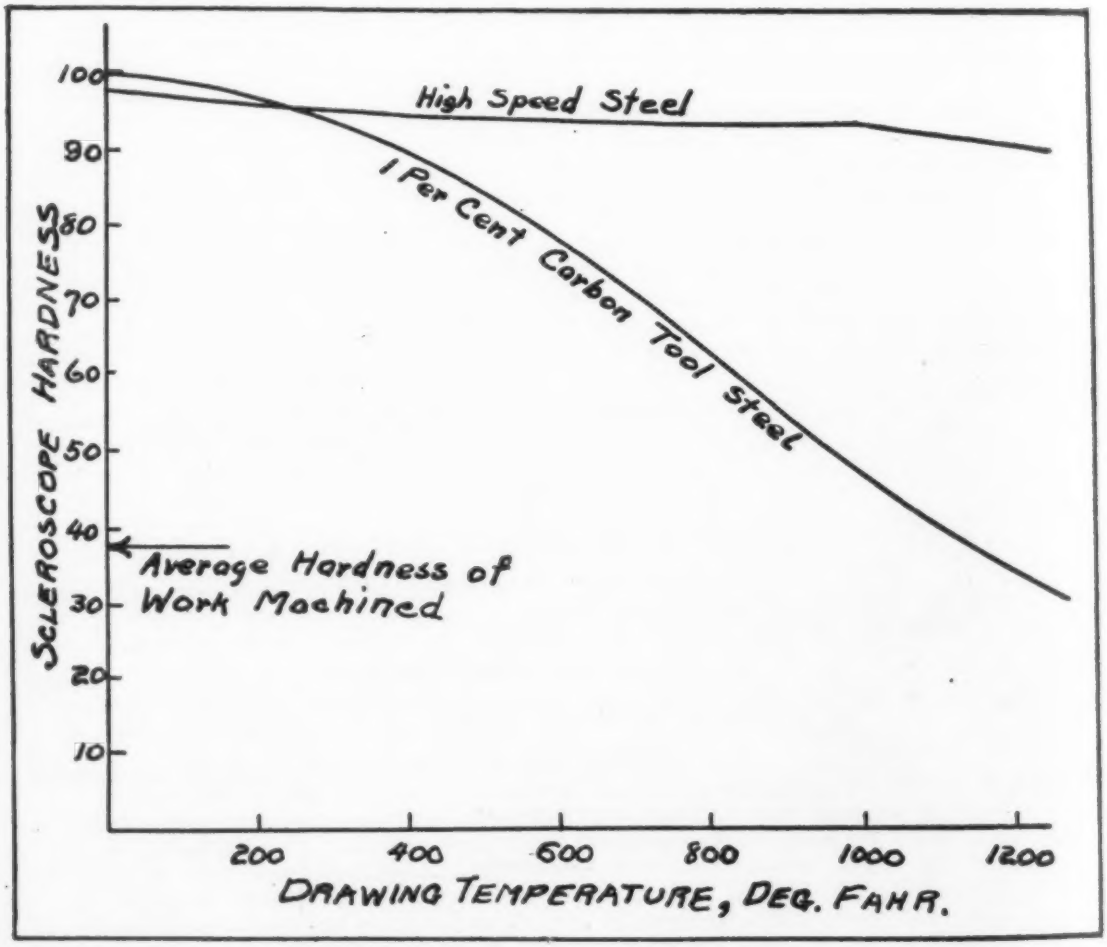

FIG. 1—EFFECT OF HEAT ON HARDENED STEEL

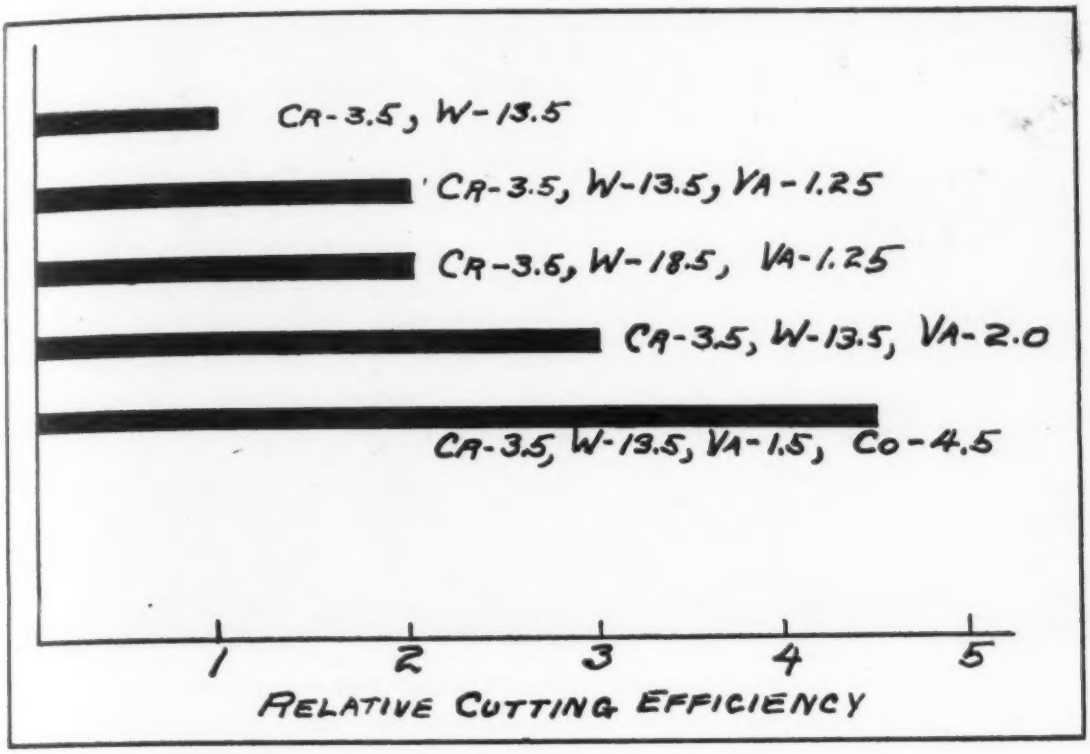

FIG. 2—COMPARISON OF VARIOUS HIGH SPEED STEELS

2. The tool must not soften when subjected to the heat developed through friction, due to increased relative speed of the tool and the work.

Tool steel, in the generally accepted sense of the word, is an iron-carbon alloy containing from 0.6 to 2.0 per cent carbon with an average of approximately 1.0 per cent carbon. The carbon exists as iron carbide, or cementite, Fe_3C, which is extremely hard, and above 1350 degrees Fahr., the stable condition of the alloy is a solid solution of Fe_3C in the iron or ferrite. Below 1350 degrees Fahr., the Fe_3C separates out of the solid solution and the stable condition is a mixture of Fe and Fe_3C, which is comparatively soft, due to the cementite being isolated in globules or plates in the soft ground mass of ferrite. If the solid solution is cooled rapidly the carbide is held in solution, resulting in uniform hardness throughout; but the alloy is in a meta-stable condition and will revert readily to the stable upon application of heat. This softening commences at about 300 degrees Fahr., and at 1300 degrees Fahr. or dull red, the steel has become very soft. This is illustrated graphically in Fig. 1.

Present high speed steels, on the other hand, when properly hardened are initially hard, and moreover there is only a small decrease in hardness when heated to a dull red; that is, high speed tools are as hard when operating at speeds where friction is sufficient to make tool red hot as are carbon steels, when operating under conditions of very light cut and feed and low speed.

The development of the modern high speed steel as shown by Table I, started in about 1866, when Robert Mushet of Sheffield, discovered the value of manganese as an alloying element of bessemer steel, giving added ease of fabrication. In the source of further ex-

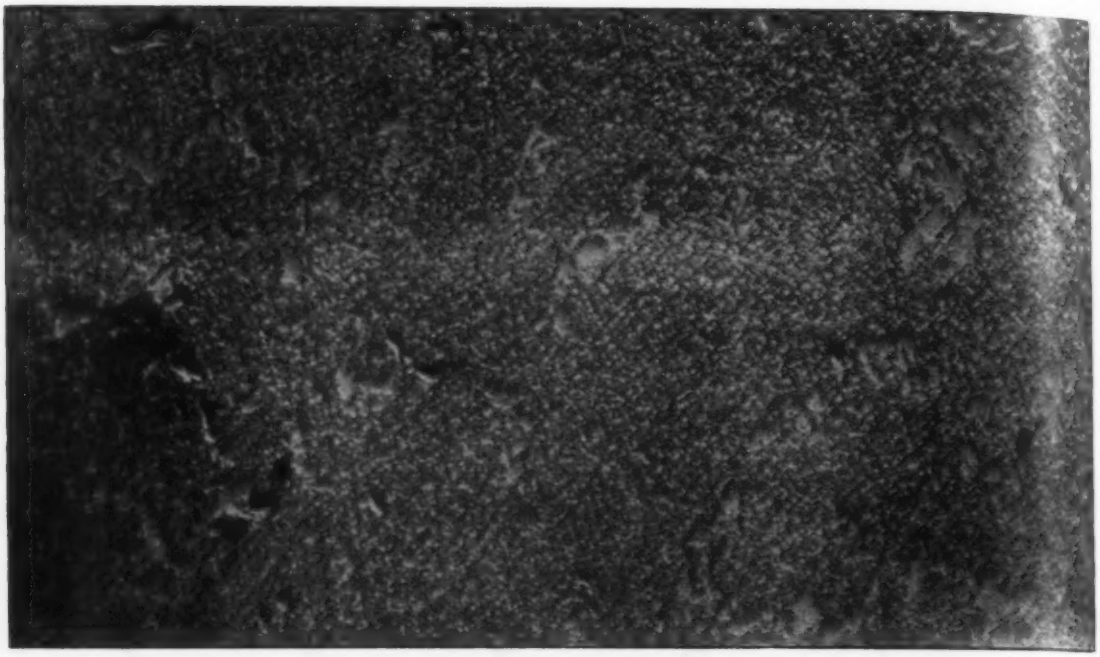

FIG. 3—PHOTOMICROGRAPH OF HIGH SPEED STEEL IN THE ANNEALED STATE X 1000

perimental work with manganese on tool steels, he noted that one particular composition possessed the property of hardening when cooled in air. This was distinctly out of accord with the knowledge of steel hardening at that time, and careful analysis developed the fact that there was considerable tungsten present in addition to the manganese, as shown by No. 1, Table I. The combination of tungsten and manganese in conjunction with high carbon resulted in a lowering to below room temperature of the point where the carbide separated out of the solid solution, giving the property of "air hardening", a term which was at once applied as a trade name to this particular tool steel. Some few years later, Henry Gladwyn, an associate of Mushet's, noted that when this steel was cooled from a yellow heat, 1700-1800 degrees Fahr., in the air blast even better results were obtained. This steel found some application in machine shops working on very hard material, but it was not generally used to speed up production, due probably to the great difficulty encountered in fabrication and dressing of tools.

It was not until about 1890 that there was any further improvement in tool steels and the next step was taken by America. Fredrick Taylor, founder of the Taylor System of Scientific Management, was at that time chief engineer at the works of the Midvale Steel Co. in Philadelphia, and was an enthusiast on the subject of increasing the production of the various machine tools. The difficulties of handling Mushet tool steel led to the discovery that by replacing the manganese with chromium and cutting the carbon content in half and increasing the tungsten content slightly, a steel was produced which had the air-hardening properties of Mushet's, was a superior cutting alloy and was readily forged to shape.

When Mr. Taylor, in 1896, went with the reorganized Bethlehem Steel Co., he continued his experiments in search of a steel with which he could increase production still more, and during the period between

1898 and 1900 he discovered the great increase in cutting speed made possible by heating the tools practically to melting point when hardening. This was a revolutionary step, as it had always been known that heating a carbon steel any higher than necessary to produce uniform solution of the carbide resulted in a coarsening of the crystallization and accompanying brittleness when hardening. In fact, a carbon tool steel heated as high as 2300 degrees Fahr. would be absolutely ruined. Further work at Bethlehem showed the advantage of higher chromium content, and between 1902 and 1906 there was in Europe and America a movement which resulted in the adoption of carbon content now generally in use 0.60 to 0.80 per cent and increasing the amounts of chrome and tungsten up to the maximum of 7 per cent chromium and 24 per cent tungsten. It was found, however, that the maximum efficiency was obtained with a chromium content of 3 to 4 per cent and 18 per cent tungsten. Molybdenum was also tried in place of tungsten, or to replace it partially, but it was found that while molybdenum produced an excellent high speed steel, it was rather uncertain and caused seams and hardening cracks so that its use was discontinued.

About the same time vanadium was added in this country, and, while it was found that it improved the cutting capacity, it was thought erroneously as it later turned out, that the increase obtained did not compensate for the additional cost entailed. In 1908-1909, Europe and America brought out simultaneously a high tungsten steel containing

Table I

Development of Cutting Alloys

High Speed Steels

No.	Year	Composition Per Cent												
		C	Mn	Si	Ni	Cr	W	Va.	Co	Mo.	Ur	Al.	Zr	Fe.
1	1868-70	2.5	2.0	.70	....	..	6.0	...	...	...	...	...	...	...
2	1890-94	1.4	.20	.25	....	1.7	8.0	...	...	...	...	...	...	...
3	1900	1.5	.30	.15	....	3.8	8.0	...	...	...	...	...	...	...
4	1902	1.4	.20	.25	....	2.5	10.0	...	...	...	...	...	...	...
5	1903	.70	.30	.30	....	3.0	13.0	...	...	...	...	...	...	...
6	1903	.70	.20	.10	....	3.0	18.0	...	...	...	...	...	...	...
7	1905	.70	.20	.20	....	7.0	24.0	...	...	...	...	...	...	...
8	1906	.35	.13	.08	....	6.0	9.0	...	...	8.0	...	...	...	...
9	1906	.70	.05	.05	....	6.0	18.0	.50	...	...	...	...	...	...
10	1908	.60	.20	.20	....	4.0	18.0	1.0	...	...	...	...	...	...
11	1910	.60	.20	.20	....	4.0	14.0	1.0	...	...	...	...	...	...
12	1913-14	.70	.20	.20	....	4.0	14.0	2.0	...	...	...	...	...	...
13	1914	.70	.20	.20	....	3.5	18.0	1.5	4.5	...	...	...	...	...
14	1915	.65	.30	.20	....	3.5	14.0	1.25	4.5	...	...	...	...	...
15	1916	.75	.30	.20	....	4.0	14.0	1.75	...	...	0.50	...	...	...
		Semi-High Speed Steels.												
16	....	1.00	.20	.20				**Carbon Tool Steel.**						
17	1868-90	1.40	.55	.25	....	...	2.0	...	...	...	...	...	...	...
18	"	1.20	.30	.20	....	...	7.0	...	...	...	...	...	...	...
19	"	.70	.10	.30	....	1.5	...	...	...	...	...	...	...	...
20	1905-10	2.5	.30	.20	....	14.0	...	...	...	...	...	...	...	...
21	1915	1.4	.30	.20	....	19.0	...	...	...	...	...	...	...	...
22	1917	1.6	.30	.80	....	12.0	...	...	3.5	...	...	...	...	...
		Nonferrous Alloys.												
23	1914	1.5	...	...	....	30.0	6.0	...	50.0	...	...	...	...	12.0
24	1916	1.5	...	6.0	65.0	15.0	...	...	...	...	...	6.0	...	6.0
25	1917	0.3	...	6.0	80.0	...	...	...	...	...	...	4.0	4.0	5.0

approximately 1 per cent vanadium which met with immediate success, and since that time vanadium has been an essential component of practically all high speed steels. Its action has never been understood fully, and there have been few attempts to explain its effect, which is to increase the life of the tool when working at high temperatures.

Shortly after this it was found that in steels containing vanadium, the tungsten could be lowered to 13 or 14 per cent with an increase in cutting capacity, which was more marked if vanadium content was increased to as high as 2 per cent. In the last few years cobalt has been added with considerable success; first in Europe and later in this country. Like every other addition which has increased the cutting powers of high speed steel, it has made the material more susceptible to abuse and has not come into very general use.

From its position in the periodic table, that is, in the Cr, Mo, W group, it seems reasonable to assume that uranium would be a valuable high speed element. Recent experiments have shown, however, that in the amounts in which it has been possible to alloy it with high speed steel, its effect is nil. It is very difficult to get it into solution in the steel due to large losses caused by oxidation or insolubility. Tantalum has also been added experimentally, but it tends to prevent air-hardening and has shown no beneficial effect. Relative cutting efficiencies are shown in Fig. 2.

Developing with the high speed steels there have grown up several alloy steels, which while not possessing high speed characteristics, have

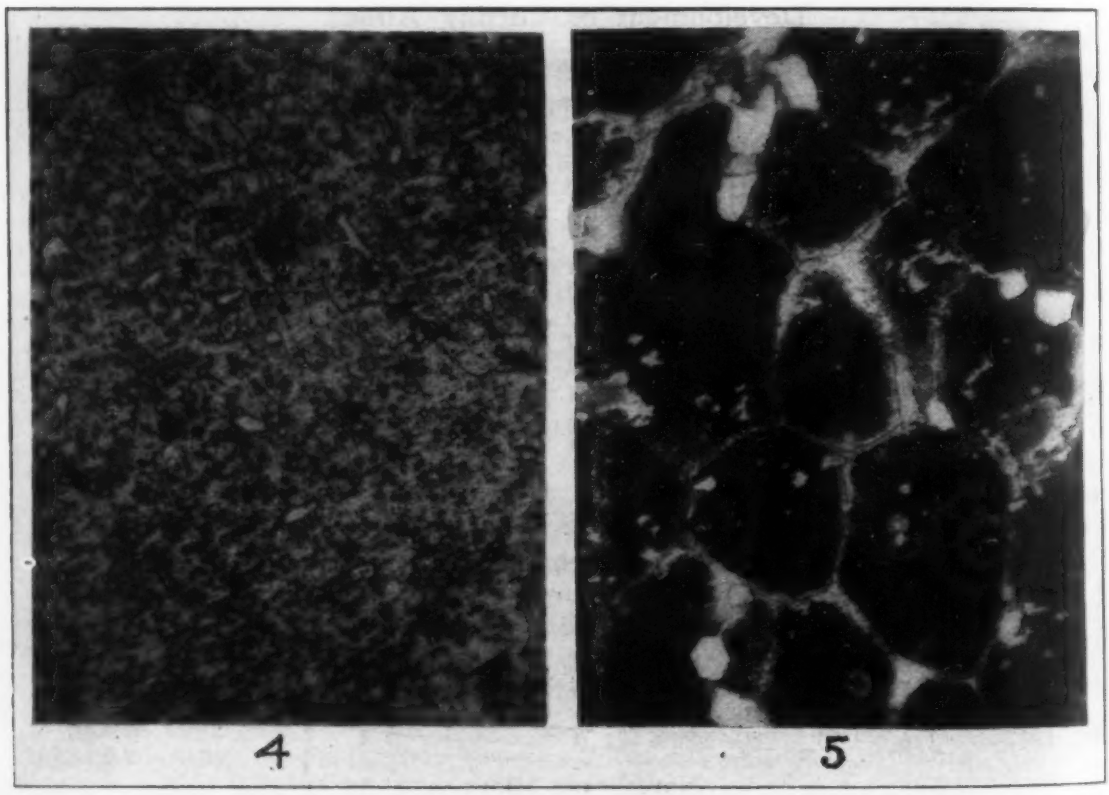

FIG. 4—STEEL HEATED TO NORMAL HARDENING TEMPERATURE. X 600. SHOWS LINES OF AUSTENITIC GRAINS, VERY LARGE. CARBIDE PARTICLES NOT IN SOLUTION. FIG. 5—CUTTER BURNED BY SEVERE OVERHEATING X 600. SHOWS PARTIAL FORMATION OF INTERGRANULAR EUTECTIC

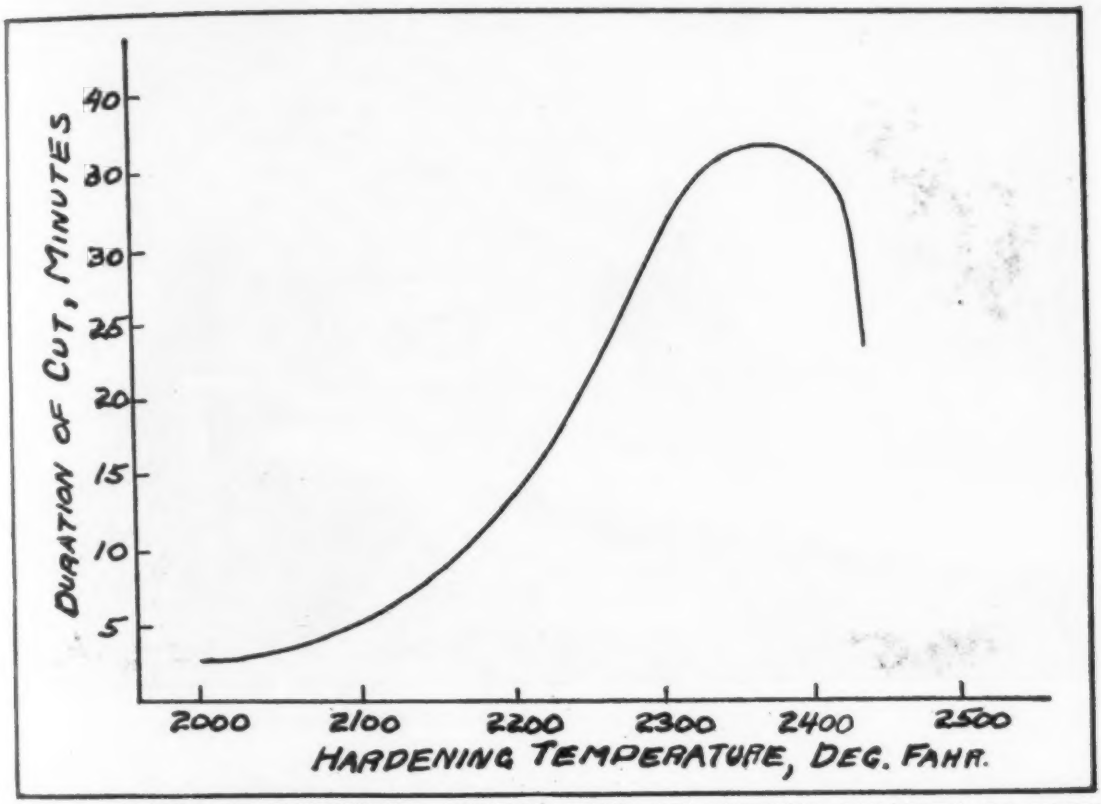

FIG. 6—EFFECT OF HARDENING TEMPERATURE ON CUTTING CAPACITY OF HIGH SPEED STEEL

found a considerable field in some classes of work where the alloying elements have produced tools possessing keen cutting edges suitable for finishing work. In the period between 1880 and 1890 tungsten was added to tool steel of 1.00 to 2.5 per cent carbon, which upon quenching from the ordinary temperatures for tool steel, 1400-1500 degrees Fahr. gave a tool possessing a durable cutting edge on light work. Later chromium was added to straight carbon tool steel, but only with the idea in mind of increasing the resistance to wear, not that of increasing speed.

In the period between 1905 and 1910, there was developed in England and France, a steel of high carbon content, 2.50 per cent, and high chrome 14 per cent. This steel possessed a very fine grain, cutting capacity far superior to carbon tool steel, though inferior to high speed steel, and moreover, the special advantage of not deforming on hardening. The hardening temperature was only 1600 to 1700 degrees Fahr. as opposed to 2200 to 2300 degrees Fahr. necessary for high speed steel. It, however, like the original Mushet steel, was difficult to forge, and on the account of the large loss in manufacture, it has been followed to a certain extent in this country by a steel of 1.5 per cent carbon and 17 to 20 per cent chromium, which possesses the same nondeforming qualities, but is more readily fabricated.

Within the last half year, in view of the scarcity of tungsten, there has been brought out in England a high speed steel "substitute", for which rather extravagant claims have been made. It is very similar to the nondeforming steels mentioned previously, with the addition of cobalt and while cobalt improves the cutting capacity over the same

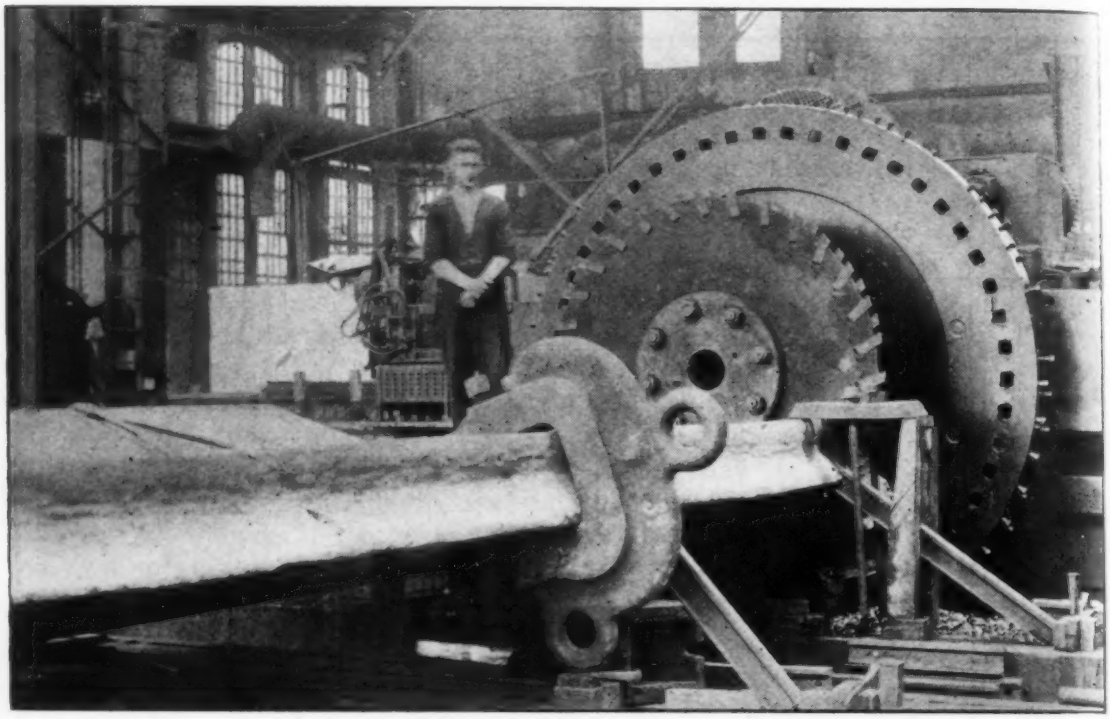

FIG. 7—COLD SAW MADE OF HIGH SPEED STEEL

steel without cobalt, it by no means is capable of working at high speed and heavy cutting conditions.

Some interesting nonferrous alloys have been brought out within the last five years, but they do not take the place of high speed steels as yet. This steel, essentially a chrome-cobalt alloy, was put on the market in 1913 by Elwood Haynes of automobile fame. It is a very hard and fine grained alloy, and although quite brittle, it is capable of extreme speed when in the hands of a competent mechanic. It may be heated to a bright red or orange, 1700 degrees Fahr., without any softening effect. It is rather high priced, due to the large percentage of cobalt.

In 1916, an English concern bought out a cutting alloy, which was largely nickel and chromium, with about 6 per cent each of aluminum and silicon. It is believed that these two elements form an intermetallic compound of extreme hardness, which is chiefly responsible for the success of the alloy, as a simple nickel-chome combination of approximately the same composition does not answer the purpose as a cutting tool.

An interesting alloy, very similar in some ways to the one just mentioned is one developed in the United States within the last year. It consists of approximately 80 per cent nickel, 4 to 6 per cent of aluminum and silicon and about 4 per cent of zirconium, a metal which is new when used in this connection. This alloy possesses a quality similar to the steel developed by Mr. Haynes though somewhat inferior; but like all the nonferrous alloys which have yet been developed, it does not possess the requisite toughness to withstand the heavy blows which high speed steel tools contend with in heavy roughing cuts or "Hogging" as it is called in the shops.

The manufacture of high speed steel involves no different processes

than those by which all high grade cutting steels have made for the past hundred years, although of course, like all other manufacturing processes, certain refinements and minor improvements are made from time to time. At the present time in this country, most high speed steel is made by the crucible process, although the electric furnace method is gaining in favor, due to the ability of the latter to refine low grade material. In the crucible process a predetermined amount of high speed steel scrap, low carbon bar iron, ferrochrome, ferrovanadium and either tungsten powder or ferrotungsten are packed in crucibles and sealed with sand or clay. Each pot holds about 100 pounds, and about 30-35 pots are put in the furnace at one time, melted and thoroughly mixed after melting by pouring into the ladle, from which the ingots are cast. As soon as the metal in the ingots is solidified the mold is stripped and ingots are cooled very slowly, either in ashes or in a soaking pit. Extreme precautions must be taken, as high speed is very sensitive to rapid temperature changes and would crack if allowed to cool suddenly.

The ingots are then annealed to remove any strains set upon casting, and are carefully heated for fabrication. The ingots may be either rolled or hammered to bars after which the latter are reannealed and are ready for shipment. It is customary to ship bars annealed in order that any machine work may be done on them.

Microscopic examination at high magnifications, 500-1000 diameters, shows that high speed steel in the annealed state Fig. 3, consists of a matrix of what is probably the solid solution of iron and tungsten, which

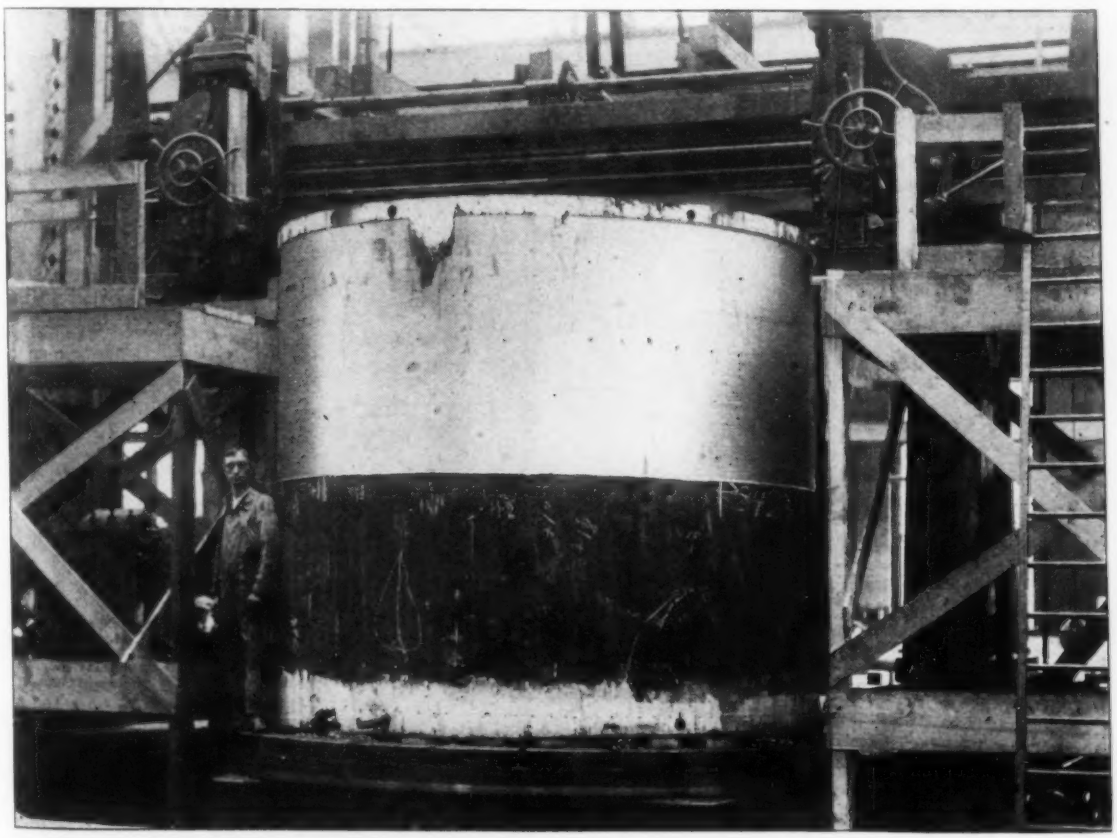

FIG. 8—VERTICAL BORING MILL USING HIGH SPEED STEEL TOOLS

is studded with innumerable globules or "ponds" which have been identified as carbides or tungstides of iron and chromium or a combination of both.

Upon quenching this steel from ordinary temperatures, that is, 1400-1700 degrees Fahr., there is practically no change in structure and there is only partial hardening, showing that solution of carbide is necessary for hardness. Tools hardened from these temperatures do not realize the possibilities in any way. It is only by heating to at least 2250 or 2300 degrees Fahr., that the carbide shown in Figs. 4 and 5, may be brought into solution and it is then only that the full possibilities as a cutting tool are obtained. The effect of hardening temperature on cutting capacity is shown in Fig. 6. There is, of course, an extreme in high temperature, and if this is passed, more injury than good results. The steel is partially melted and an intergranular eutectic, which is extremely brittle, is formed upon cooling. This eutectic structure cannot be broken up by annealing and is always a source of trouble.

There have been several theories advanced for the selfhardening properties and so-called red hardness of high speed steels, none of which are entirely satisfactory, but all of them have their adherents. To show the trend of opinion the following theories of self hardening and red hardness are enumerated:

1. *Bohler*—"Wolgram & Rapidstahl"—Wien, 1904.

Austentite pearlite transformation is suppressed with increase in chromium and tungsten and furthermore the higher the initial temperature the greater the suppression of this point resulting in eventual lowering below the room temperature.

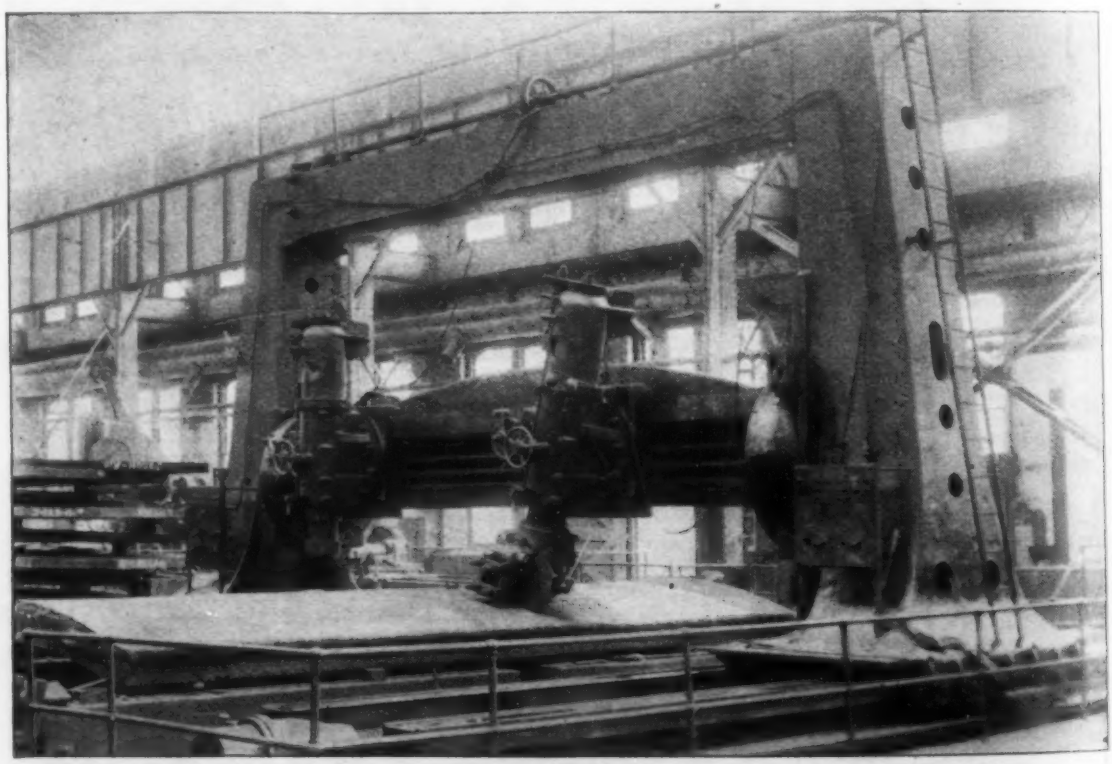

FIG. 9—ARMOR PLANER UTILIZING HIGH SPEED STEEL TOOL

2. *Osmond*—Paris. Chromium and tungsten lower the carbon content of pearlite, making steel of 0.60 to 0.80 per cent really a hypereutectoid steel, and furthermore prevent separation of cementite, so that the rate of cooling has little effect. An increase in the carbon content results in the lowering of transformations, so that by varying the amount of carbide in solution, that is, by heating to higher temperatures, these transformation points are lowered to room temperature with an austenitic structure resulting. No particular explanation of red hardness is given.

3. *Carpenter.* Tungsten and chromium promote retention of the austenitic structure due to lowering of the transformation points cooling. Upon drawing, austenite is converted to martensite with the result that at a temperature of 1000-1200 degrees Fahr., high speed steel is as hard as carbon steel at ordinary temperatures.

4. *Edwards*—Manchester.

A—Formation of tungsten carbide at 2200 degrees Fahr., and solution of this carbide at 2350-2400 degrees Fahr.

B—Assumes that chromium combines with carbon and goes into solution at once on passing Ac range, but that tungsten does not go into solution until temperature of 2300-2400 degrees Fahr., is reached. The chromium is responsible for air hardening properties of the steel. Edwards accounts for red hardness as follows: Upon drawing a straight chromium alloy, there is a gradual decrease in hardness, while on drawing a straight tungsten alloy there is an increase up to 1000-1100 degrees Fahr., and then a decrease, therefore complete solution of tungsten is necessary to produce secondary hardening.

5. A theory which seems plausible would be a combination of

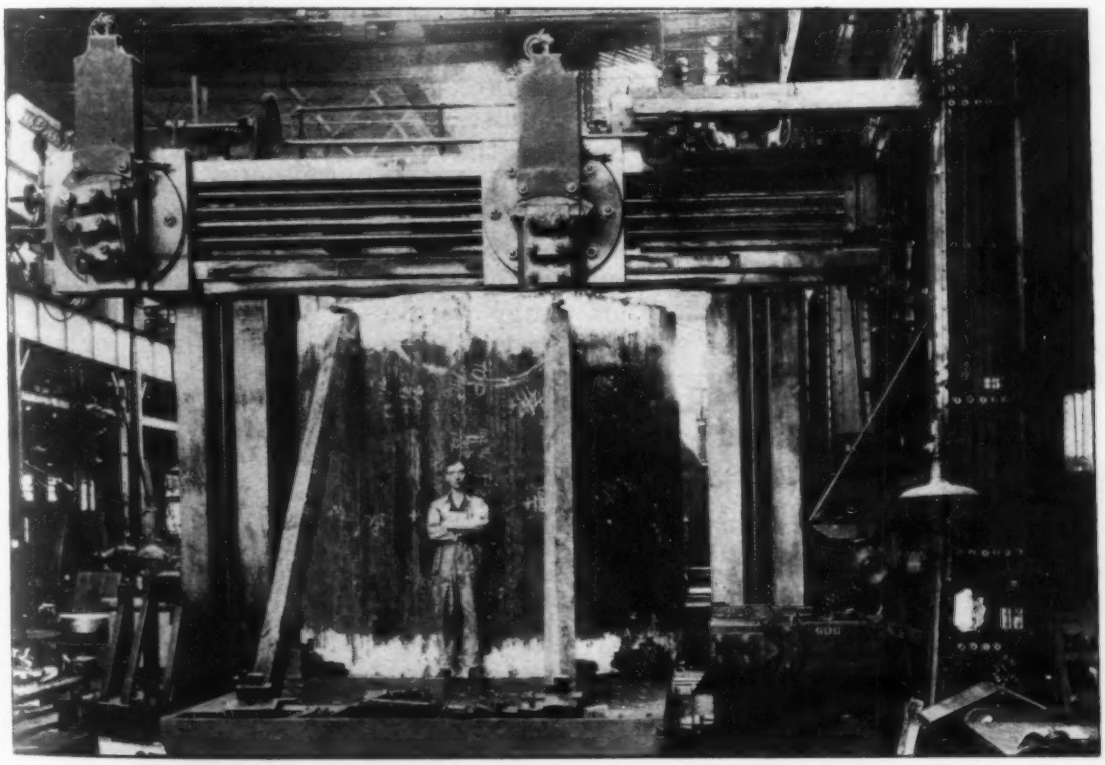

FIG. 10—MODERN PLANER HAVING HIGH SPEED STEEL TOOL

Osmond and Carpenter; namely: Chromium and tungsten lower the carbon content of pearlite, thus accounting for an excess of free carbides seen in annealed high speed steel of 0.60 - 0.70 per cent carbon. This is further partially verified by microscopic examination, which shows at high magnification, a structure of the matrix resembling very fine pearlite with no excess ferrite. Furthermore, chromium and tungsten prevent separation of cementite, so that the rate of cooling has little effect. An increase in carbon content further lowers the transformation range, so that by heating to high temperatures and obtaining a complete solution of carbide, the transformation range is lowered below room temperature, resulting in the austenitic or polygonal structure whether cooled rapidly or moderately slow.

The red hardness is due to the conversion upon heating of the austenitic structure to martensite, which theoretically increases the hardness and which many investigators have found to be the case. Personally, the author has not found an increase, but has found that the hardness remained practically constant. In view of the extreme sluggishness with which the carbide goes into solution upon heating, it is natural to suppose that it will separate out of solution just as sluggishly upon reheating, thus accounting for the long time a high speed tool will run at red heat before failure. Commercial applications of high speed tool steel are shown in Fig. 7 to 10.

As a practical result of high speed steel we need only look around the manufacturing establishments of today and compare with similar plants 20 years ago. The development of the present rate of production has been the result of a contest between the steel manufacturer and the machine tool manufacturer, with the producer as an interested spectator. The supremacy has alternated between the two contestants: first, one having a tool steel capable of higher speed than the machine would stand, and the other retaliating by building a machine of ample strength and free from vibration which would withstand a speed capable of burning up the tool. At the present time, the manufacturers of machine tools leading, and the next advance must be made by the steel manufacturer. Personally, the author believes that a cutting alloy whose hardness is not dependent on carbon and which is unaffected by heat is the coming high speed tool. The realm of alloys has yet only been touched since the number of alloying elements available and the possible combinations will give an infinite number of resulting compositions out of which can be found, one alloy or range of alloys which will have the toughness and keenness of steel and the heat-resisting qualities, or red hardness, of the present day nonferrous alloys.

HEAT TREATMENT OF HIGH SPEED STEEL

By J. L. Thorne

THE art of heat treating high speed steel is the most important branch of the cutting tool industry of today. It is even of more importance than good steel, careful designing, or of any other individual step in the process of manufacture for the reason that heat treating is usually one of the last operations, and all the good qualities that a tool might have possessed are readily destroyed in a greater or less degree by improper heat treatment. Realizing the importance of this operation, close attention should be given to every detail which will enable the operator to insure reliable results.

Steel being the raw material from which all tools are made should receive careful study and that grade which is best adapted for the particular purpose in mind selected. Many steels on the market today have adopted what is practically a standard chemical composition. This composition was selected because for standard work it has proven itself to be good. However, let us not make the mistake of being too conservative by refusing to try any new steel or alloy which may possess merit to a high degree. From the heat treating point of view, it does not matter by which process the steel is made, either the crucible or electric. Both methods make good and poor steels, depending entirely upon the skill and knowledge which are used in its manufacture. In a general way the chemical composition of high speed steel is as follows:

	Per cent
Carbon	0.60-0.70
Silicon	0.20-0.30
Sulphur	0.025 maximum
Phosphorus	0.025 maximum
Manganese	0.25-0.35
Chromium	3.25-4.00
Vanadium	0.25-1.00
Tungsten	16.00-18.00

Before going further, it might be well to consider the effects of these different elements upon the steel.

Silicon when too high causes a brittleness by forming a silicon of iron which is not appreciably dissolved in the steel and acts in much the same manner as any foreign inclusion.

Manganese is of great benefit to the steel, in that it readily combines with the sulphur and reduces to a minimum the damage this element would do if left to combine with the iron. Manganese, however, is nearly always in excess of that needed to combine with the sulphur and the remainder unites with the carbon to form manganese carbide which is one of the compounds which in part hardens tool steel.

Sulphur, if left uncombined by the manganese would form a compound with the iron which would be of a very brittle nature. As stated before, however, it is seldom in excess of the manganese and is injurious for the reason that manganese sulphide does not enter into the solid solution, but separates out as an inclusion in the steel. Sulphur causes steel to be brittle

A paper presented before the Philadelphia Convention. The author, J. L. Thorne, is metallurgist, High Speed Steel Tool Corp., New York.

when hot, and if too high it is impossible to work the steel through the rolling mills and necessarily scraps the ingot.

Phosphorus unites with the iron to form a phosphide which often segregates and causes the other compound, such as the carbides, to become segregated, and it is said to be one of the chief causes of ghosts lines in steel. Phosphorus also causes the steel to be sensitive to shock.

Chromium does not materially alter the critical range, although it has been claimed to slightly lower the upper critical points. This element in conjunction with the carbon is mainly responsible for the extreme hardness of high speed steel. It is very influential in causing the steel to be hard on relatively slow cooling after being heated through the critical range, and it also imparts a secondary hardness on being reheated to a temperature under the critical range.

Vanadium was originally used as a scavenger of the steel to remove in the slag impurities and to reduce the amount of nitrogen held occluded in the steel. However, it is now proven that this element adds some very desirable qualities to the steel. It increases the elastic limit and greater resistance to wear and shock, allowing the steel to have a higher cutting rate when properly heat treated.

Tungsten slightly raises the critical range and unites with the carbon to form a double carbide. This element increases the desirable effects of chromium and imparts the high degree of red hardness which makes our high speed steel so valuable.

While this does not begin to exhaust the effects due to these various elements on the steel, it, in a general way, gives some idea of what the steel is composed and why the various elements are added. It also explains why the tool manufacturer lays as much stress as he does on the importance of purchasing steel of a specified analysis. On the whole the chemical analysis of the steel has no direct bearing on the heat treatment it will receive, aside from the fact that these various elements cause a change in the position of the critical range. The critical range itself is of secondary importance. The main fact which the heat treater should know is the temperature necessary to cause the various elements to enter into the solid solution and form a homogeneous compound. The following treatment is for the usual high speed steel on the market and as the composition varies with higher or lower percentages of alloys, the heat must be varied to meet the new conditions. With high speed tools which are cast to shape the heat treatment is altogether different in every way, from that described. It was because of our trying to heat treat cast tools in the same manner as we had formerly heat treated tools made of bar stock that we had encountered many failures and very uniform results. After a careful study of our cast tools, a new method for heat treating was worked out.

To illustrate some remarkable instances of what improper heat treatment may cause even with a high-grade metal, it may be well to give some of the results resulting from the usual heat treatment given high speed steel on cast tools and compare them with the results now obtained using an altogether different method. In heat treating tools cast to shape as ordinary high speed steel we found, as did many others, that breakage was very high, due to hardening strains and to the reason that cast tools do not have the fibrous structure that steel which has been hammered and rolled has, and, of course, if no corrective measures are taken, is of a brittle nature. This has been overcome by heat treating and in course of time, when some existing experiments have

been completed showing the relation of cutting ability to results from impact tests, tensile strength and elastic limit in conjunction with the hardness of the tool, we hope to present this information for your consideration.

Even with our limited knowledge of the cast iron tool industry, we have obtained cutters which will uniformly do the following work—a 6 x 1-inch milling cutter was used and the material cut showed a shore hardness of 38, the speed was 83 revolutions per minute or a cutting speed of over 130 feet per minute, depth of cut 1-inch feed, 16 inches per minute. This means we can remove 16 cubic inches per minute, or one cubic foot in little over one hour and a half.

Heat treating of commercial high speed steel consists essentially of first preheating the tool; second, raising it to the high temperature; third, quenching, and fourth, reheating, drawing or tempering. To accomplish these four operations successfully the form of the furnace should be carefully considered in its relations to the type of the tool to be hardened. For the purpose of this article, we will take into consideration such tools as are properly hardened in an oven-type furnace. This would include all milling cutters, blades, forming tools, etc., which are to be hardened all over.

The purpose of preheating is to raise the temperature to some point below the critical range, so that on its introduction into the high temperature furnace, it may acquire that temperature as quickly as possible. While it is necessary to leave the tools in the preheating furnace for some little time, care must be used that as small an amount of scale as possible is formed on the tool. The reason for this is that the scale when heated to a relatively high temperature is reduced again by the carbon of the steel and causes a decarbonized surface. There are many cases where steel has been condemned for this soft or discarbonized surface which was entirely due to an improper atmosphere within the furnace, this causing the scale. It has been found that the smaller tools of delicate shape could be preheated to high temperature as 1700 degrees Fahr. with good results, as it is not necessary to hold these pieces in the high temperature furnace for as long a time as would be necessary had the temperature been lower in the preheating furnace. In general, experience has proven that the higher preheating temperature gives better results than by following the older methods which use approximately 1500 degrees Fahr. for all preheating work.

The main points to be considered in the preheating furnace are: first, uniformity of heat; second, temperature to which the piece is to be raised; and third, the atmosphere within the furnace to obtain the least possible amount of oxidation of the tool. In preheating the tool, it should be brought to the temperature slowly, as this will eliminate the danger of checking the steel due to the uneven expansion of the tool. This is especially true of tools which are not of uniform cross section. From the preheating furnace, the tool is now transferred as quickly as possible to the high temperature furnace.

The object of the high temperature furnace is to cause the various elements in the steel to enter into a solid solution in the quickest possible time. The reason for haste is that as soon as the steel passes the critical range, grain growth sets in and the smaller we can keep the grain and at the same time acquire a homogeneous solution, the better service we may expect from the tools. Excessive grain growth causes brittleness in the tool and drawing even at high temperature cannot correct this, although it may mitigate the brittle nature to some extent. On account of this grain growth, the preheat-

ing should be as high as possible but lower than the critical range and the temperature of the high heat furnace considerably higher than that to which the tool is to be brought. For ordinary high speed steel a furnace temperature of not less than 2350 degrees Fahr. and as soon as the operator is able, this should be raised to 2375 degrees Fahr. or even higher. At this temperature the steel would soon be destroyed if left for any considerable time, and must receive careful attention and removed the instant the fine cutting edges acquire the proper temperature. The usual method to determine the proper time to remove the tool is to watch for the metal to sweat or small bubbles to appear on the surface of the tool. This method is good, but a better way for the careful observer is to watch the thin section of the tool and when the tool is ready to be removed a faint but noticeable intensity of color is observable. This increased intensity lasts but a very short time and if not observed, there is danger of the tool being overheated. It resembles in many respects the recalescence of plain carbon steel and is no doubt due to some changes taking place in the steel. The tungsten carbide will go into solution at a temperature much lower than has been recommended in this paper, but it is sluggish and to get it in solution takes time, allowing grain growth, although for the heat treater who has had little experience with high speed steel it is no doubt safer even if it is at the expense of the cutting ability of the tool.

It is of prime importance to heat cutting edges to get even uniformity, etc. To accomplish this, it is necessary to resort to many little tricks. All tools should be moved so that both sides shall attain the same temperature and for milling cutters, the writer has found that a block of pure nickel upon which they may be placed so that the cutting edges extend over the edges of the block assists in bringing the tool to a uniform heat. Tools which have a large and small cross section may be brought to heat evenly by protecting the thinner sections with asbestos for a portion of the time and removed so that all parts acquire the temperature necessary at the same instant. Angular cutters may be placed with the thin section next to the hearth bottom and are thus protected by their own mass and the thin sections are the last to acquire the necessary temperature.

Where many pieces are treated daily, the scale from the tools falls to the hearth and in the high temperature soon fluxes with the hearth to form a thick slag which does not help in heat treating and more often damages the fine cutting edges by promoting fusing of the steel. This slag often adheres to the tool after quenching and when it is sand blasted enough to remove this slag the cutting edges often suffer. When the hearth gets bad a sheet of asbestos covering the hearth will help considerably, although it requires renewing almost daily. In connection with the hearth, it has been found that carborundum is much better than the ordinary fire clay. The cost is two to three times as much, but gives nearly ten times as much service. In one heat-treating room the bottoms made of fire clay lasted on an average ten days. Carborundum hearths were tried and they gave better than three months' service. This, when the time lost in renewing the hearth is taken into consideration, more than paid.

Another source of trouble in the high temperature furnace is protection tubes to withstand a temperature of 2300 degrees Fahr. or higher. Most of the alloys on the market fail to stand up for any time at all and the refractory tubes have numerous faults. In the first place, it is hard to introduce a new protection tube into a hot furnace without first preheating on account of

breakage, due to the expansion of the tube. Even when put in a cold furnace and brought up to heat with the furnaces, they sometimes break for this reason. Another bad feature is that they are easily broken by being struck by the work in the furnace. As a substitute for the various protection tubes on the market using pure nickel tubes made from nickel bars with the holes drilled or bored is suggested. Cast nickel tubes were tried and while they were far superior to any that had been used before, they gave less than half the service the bar tubes gave and were more or less porous. The bar tubes have given service for three to nine months where the temperature used was from 2350 to 2385 degrees Fahr.

The tool having been brought to the desired temperature and the steel being in a solid homogeneous solution, it is necessary to quench the tool so that it is cooled quickly, thus the complexed hardenites do not have time to separate out and acquire that form in which the steel would be soft. Fortunately for the heat treater this takes place in high speed steel at a comparatively slow rate and even cooling in air is rapid enough to retain these hardenites in the form that will render the steel hard. However, to follow this practice a large amount of scale forms which reduces the size of the tool, causes pitting and in many ways impedes subsequent operations, however, it is still sometimes used, more especially in Europe. To overcome these objections the tools formerly were immersed in oil when removed from the high temperature which cooled fast enough to keep the steel hard. There are many objections against the use of oil, however. Some of these are: First, the oil often takes fire when large quantities of hot metal are quenched and unless expensive cooling devices are installed is dangerous. Second, the oil cools the tool too quickly and often causes the tools to check, especially when of uneven cross area. This is is especially true if the oil contains moisture and water often gets into the oil from the water jackets usually employed to keep the oil cool. Third, the oil becomes spilled or drips off the tools when they are removed and in this respect is dirty and causes the floor to become slippery, which is dangerous to the workmen. For these reasons as well as others not mentioned, heat treaters have discarded oil for high speed steel to a large extent and have substituted various salt baths which have a relative low melting point and are soluble in water. This bath should be kept at a temperature of about 1100 to 1130 degrees Fahr. The merits of this method of quenching eliminate the danger of checking the steel as the change of temperature from the high temperature furnace to that of the bath is not as great as in the case of oil and the amount of contraction and strains set up in the steel is correspondingly less. The heat is conducted away from the tool more slowly in the salt bath than in oil, but fast enough to retain the hardenites in their proper form. As soon as the steel has acquired the temperature of the bath, it is removed and allowed to cool to some point below 650 degrees Fahr.

The tool is now hard but contains the strain set up in quenching and the full red hardness has not been brought out to the maximum. To get these results it is necessary to temper or draw the tool. This may be done in the same salt bath or one kept especially for the purpose. Experiments conducted to determine the proper drawing temperatures showed the following results as the temperature of the draw increased from 350 to around 700 degrees Fahr. the scleroscope showed a decrease in hardness. From this point up to nearly 1200 degrees Fahr. the scleroscope showed an increase in hardness

with the increase in temperature. Some metallurgists attribute this to the fact that it is during this latter range of temperature that the red hardness of high speed steel is developed. While the scleroscope showed the steel to be harder at, say 1100 degrees Fahr. than at 700 degrees, a test made with a file showed the tool to be softer. On actual cutting test the higher drawing temperatures always gave better results. This shows conclusively that neither scleroscope nor the file alone will give any indication of what a tool will do in actual cutting tests; but if they are used together they will indicate to a large extent just what may be expected of them. For general purpose a drawing temperature of 1130 degrees Fahr. is recommended, but if the operator is positive that his temperature recorders are correct, this drawing temperature may be carried up to 1175 degrees Fahr. Exceeding this temperature very much again causes the steel to become softer until the annealed condition is approached.

In conclusion it may be said that with care in handling and with a reliable pyrometer equipment, anyone should be able to heat high speed tools and obtain creditable results. The quenching and drawing in molten salts eliminate many of the dangers which formerly followed the old practice of using oil for these two operations. Lead baths have been used as a means of drawing, but on account of the lead adhering to the tool, particularly if there be scale on the steel, and the difficulty of its removal makes its value a doubtful one. Lead is also rather too good a conductor of heat to be the ideal bath for these operations. The exhausted cyanide bath will answer very nicely for both the quenching and drawing baths.

DISCUSSION OF MR. THORNE'S PAPER

MR. REARDEN: What would you consider in drawing would be the proper temperature for the bath in oil?

MR. THORNE: Personally, I would not use oil. I would use a bath at approximately 1100 degrees Fahr. for quenching.

MR. REARDEN: Suppose that is not available. Suppose you use the oil?

MR. THORNE: I would have the temperature of my oil at least 125 degrees Fahr.

MR. REARDEN: What would be the final point for a cutter edge three-quarters inch in diameter, 4 inches long?

MR. THORNE: I would say, off-hand, 1130 degrees Fahr. depending, of course, on the initial heat. If you have the tungsten entirely in solution, 1130 degrees Fahr. and perhaps even higher would give very good results.

MR. KANE: In protecting the thin parts of tools will it be a whole lot easier to take a cold bar and hold over the part you want to keep down where it has a tendency to heat faster, instead of wrapping with asbestos?

MR. THORNE: It all depends on the shape of the part that you are trying to protect. Any method that will hold the heat back. It was not the idea to wrap the piece, but simply laying a piece loosely over it in protecting it, I have often found even that simple method would hold the heat back, but any other method that would hold the heat back, if you can spot the heat with a rod or anything of that sort would answer equally as well. The main thing is to get it to come to an even temperature at the same time, just before quenching.

MR. REARDEN: The oil being at a lower temperature than 125 degrees Fahr. would probably cause the cutter to crack, would it not?

MR. THORNE: It would certainly be more of a severe shock set up. What we call quenching strains would be more apt to cause checking than the other method.

MR. JENSEN: I would like to ask the question—I run my steel up to 2250 degrees Fahr. and still it is soft, so you can file it with a file. On heating it up again and quenching it in oil it cracks. What is the trouble?

MR. THORNE: There are several things that might be wrong. It may be that you are not getting your steel in solution. It may be that your atmosphere is bad and you are decarbonizing the surface. On reheating, without annealing and quenching in oil, you very often get the checking due to strains set up by a double quench without relieving any of those strains. The mere fact of reheating up to a hardening heat without a prolonged annealing does not seem to relieve those strains, although you might think it would.

MR. THOMPSON: In quenching from high heat in oil is it better to hold the tool steady in the oil or set up a motion?

MR. THORNE: I personally discontinued the use of oil about five years ago, or perhaps six years ago, but up until the time that I discontinued using oil I found that I had less distortion by holding the piece still, and the piece is cooled rapidly enough, even at that, unless a piece is very large, so it is not necessary to rotate it in the oil bath.

MR. STENGER: I have been told of wonderful results that have been obtained by carbonizing high speed steel, also by covering the work with cyanide compounds when heating in the higher heat. I am wondering if Mr. Thorne could tell us something about carbonization of high speed steel and what effect it has.

MR. THORNE: I can tell you my experience with it is a very simple matter. It was disastrous, although I don't doubt but that a high speed steel can be carbonized or that it can be hardened, but at the time I tried it and was fooling with that stuff it was very disastrous to me.

VOLUME CHANGES IN THE HEAT TREATMENT OF STEEL

By Leslie Aitchison

CHANGES of structure occur during the heating and cooling of steel are of great, in fact essential, importance, and are the fundamental facts underlying the possibility of the changes in mechanical properties which can be brought about by heat treatment. Without going too far into the subject it may be desirable to mention the most essential features of the changes which occur. If a carbon steel is heated, a certain definite alteration occurs in its constitution when the steel reaches a predetermined and fixed temperature or very narrow range of temperature. The change which occurs at what is known as the "lower critical" or "carbon change" point, which is found at a temperature of about 730 degrees Cent., consists of the formation within the steel of a solid solution. At ordinary temperatures the steel, if it has been cooled normally, contains a constituent known as pearlite, which is a mixture of fixed proportions of iron and iron carbide.

When this mixture is heated to the lower critical change point it is transformed from a mixture into a solid solution. The two constituents of the mixture, iron and iron carbide, mutually dissolve one in the other to produce a solution of iron carbide in iron. The transformation takes place at a definite temperature and occurs almost instantaneously. The resulting solution is a true solution, and the only difference between it and, for instance, a solution of sugar in water, is that the latter is liquid and the former is solid. If the solid solution is heated to a higher temperature than the critical point, it will dissolve into itself whatever other constituent may be present in the steel either excess iron (ferrite) or excess carbide (cementite), until finally, when the upper critical point is reached, the whole of the steel consists of solid solution.

The changes produced in the steel by heating, of course, have a considerable effect upon the mechanical properties of the steel, particularly if it is cooled rapidly from a high temperature. There are other changes, however, which take place in the steel as a result of the constitutional changes described above, and these are related to the volume of the steel. The solid solution which is formed at high temperatures has a different specific gravity from that possessed by the mixture from which it is formed. The steel in passing from the condition of a mixture to that of a solid solution contracts and occupies a definitely smaller volume while in the form of a solid solution. Similarly, when the reverse structural change takes place, there is an opposite volume change, an expansion, since the mixture occupies a larger volume than the solid solution.

It must be made perfectly clear that these changes of volume always accompany the corresponding changes of structure and that they cannot be suppressed or eliminated. They are essential properties of the steel. Thus, whether the steel is cooled rapidly or slowly, the volume changes will occur, provided that the constitutional changes take place also.

The changes of volume described above necessarily occur at the critical temperatures. Before proceeding to discuss what these changes mean, it is desirable to mention that during the heating and cooling of steel other volume changes take place. These, of course, are the comparatively simple

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and regular changes of volume which occur when steel is heated or cooled, due to ordinary thermal expansion and contraction. It is well known, of course, that steel expands when it is heated and contracts when it is cooled. Moreover, the extent of the expansions and contraction is found to be more or less regular over the whole range of temperature between zero degrees Cent. and the critical temperature. The normal changes mean, therefore, that when heated to any temperature the steel expands and when cooled it contracts. The abnormal changes due to the alterations of structure mean that a steel contracts when heated through its critical temperature and expands when cooled. In other words, the abnormal and the normal volume changes act in opposite ways. The nature of the complete changes is shown in Fig. 4, which represents all the alterations of volume which occur when steel is heated or cooled from room temperature to 1000 degrees Cent.

The above facts have a very considerable influence upon the heat

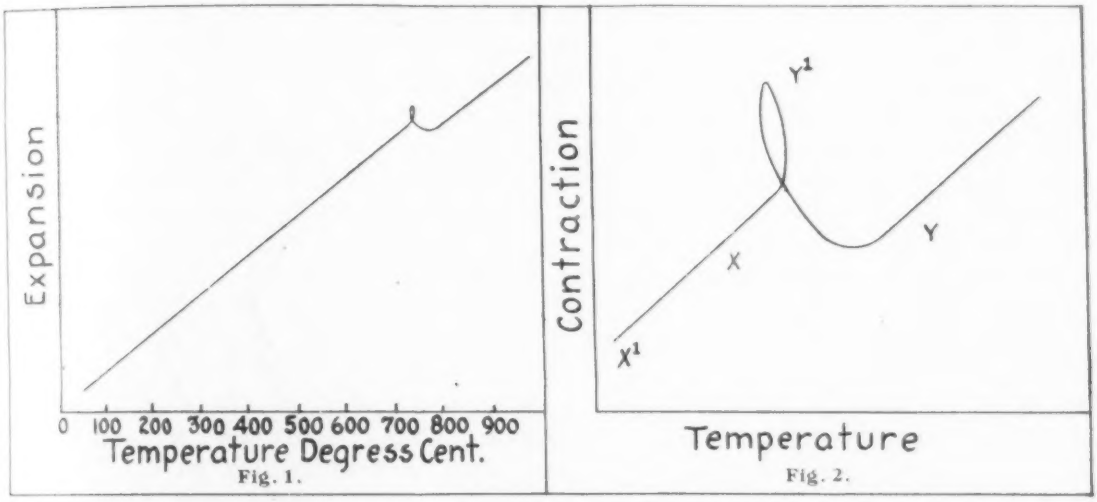

FIG. 1—CURVE WHICH SHOWS THE ALTERATIONS IN VOLUME WHICH OCCUR WHEN STEEL IS HEATED OR COOLED FROM ROOM TEMPERATURE TO 1000 DEGREES CENT. FIG. 2—DIAGRAM ILLUSTRATING HOW SOME LAYERS CONTRACT WHILE OTHERS EXPAND WITH THE RESULT THAT STRESSES RESULT.

treatment of steel. Before they can be discussed really profitably, however, it is desirable to examine the processes of treatment rather more carefully. It may be said at once that the only heat treatment operation which is affected seriously by volume changes is the hardening process. This process, as is well known, consists in the more or less rapid cooling of the steel from a temperature as near as possible to its upper critical point. At this temperature the steel consists entirely of solid solution, and the aim of the cooling process is to retain this solid solution more or less intact during the time that the steel cools to atmospheric temperatures. Unless this result is achieved, the steel is not hardened properly.

It is well known that all steels do not harden to the same extent nor with the same ease. Some steels have to be cooled in water, others in oil, while others again will harden if cooled only in air. These facts point to the conclusion that every kind of steel has its own particular critical rate of cooling which must be achieved or exceeded if the steel is to be hardened. If the steel is cooled at a slower rate than the critical, the solid solution

which is formed at the high temperatures will be wholly or partly decomposed during cooling.

It is equally well known that during the cooling of a piece of steel or for that matter of anything else, the rate of cooling of the interior is slower than that of the exterior, and therefore, that, whereas a piece of steel when quenched may cool on the outside at a speed equal to or greater than the critical rate of cooling required to harden the steel, the interior of the same piece cools at a rate lower than the critical. The result is that the exterior of the part is hardened and the interior is not hardened. As a consequence, the solid solution which existed at high temperatures on the outside of the part remains intact during the cooling down, but that which existed in the interior of the part is decomposed either partially or completely according to the depth of the particular point below the surface. The above facts are quite familiar under the term of the "mass effect" in hardening.

It is now time to inquire in what way the volume changes which occur during the heating and the cooling of the steel affect the steel during hardening. It may be said at once that the only volume changes which affect the steel in any adverse way are the abnormal changes occurring at the critical temperature in consequence of the alteration of the structure of the steel. The ordinary volume changes due to normal thermal expansion and contraction have no detrimental effect upon the metal. Imagine the case of a piece of steel, either spherical or cylindrical. In the latter case, imagine the cylinder to be very long, sufficiently so that by concentrating attention upon the steel at the middle of its length, the effects of the ends of the cylinder may be neglected. When the steel is hot it is at a uniform temperature throughout. Let it be taken out into the air and allowed to cool as it will. There will be at any time a gradient of temperature from the inside to the outside of the piece, so that every layer will be slightly hotter than the next exterior layer and slightly cooler than the next interior layer. Suppose that the cooling starts from a temperature well above the lower critical point. During the time that the steel is above this temperature every part of the steel will contract more or less uniformly, the outer layers always contracting upon the inner because the latter, being at the higher temperature, will have contracted somewhat less than they will when temperature equilibrium has been established. That is, however, of little importance.

When the outermost layer cools down to the critical temperature it will suddenly expand and then continue to contract once again according to the process of normal thermal contraction. Its volumetric alterations are shown in Fig. 2. The second layer will go through similar alterations of volume, as will each successive layer. After a few layers have passed through the complete change, the outermost layer has cooled distinctly below the critical temperature and therefore has a volume distinctly less than it had at the time that it passed through the critical volume changes. Its volume may be indicated satisfactorily by the position X on the diagram in Fig. 2. A layer a little deeper in the specimen will have a volume indicated by the position Y in the figure. When the temperature of the steel has fallen a little lower, the volume of the outside will be say X^1 and that of the deeper layer will be Y^1. In other words, the outside has contracted a little and the inside has expanded. This is bound to mean that the outside of the part is stressed to some extent. The value of the

stress will probably be quite small, since the steel is cooling normally and no harm is likely to be done. Nevertheless, some stress by necessity will be exerted on the outermost layer of steel.

The next condition to consider is slightly different. Suppose that the steel is quenched at a rate sufficiently high to harden the steel. This means that the rate of cooling is high enough to retain the solid solution intact and to prevent it from decomposing. Each successive layer of the steel, therefore, avoids the expansion, and the only change that will occur will be that due to the ordinary normal thermal contraction of the part. Suppose, however, that the steel suffers from mass effect and does not harden completely through. There will be abnormal volume changes in one part and not in another part of the piece of steel.

In the outside there is no structural change and as a result no abnormal volume alteration. In the interior both structural change and consequent volume change occur. It will be well, therefore, to examine more closely the results of these alterations.

Since the outside of the material undergoes no structural change, its volume, particularly at temperatures near to the critical point, will be very much less proportionately than the volume will be if it has undergone a normal expansion. On the other hand, the interior of the part in which the structural changes have occurred will have expanded, and consequently will put a considerable stress on the outside nonexpanded layers. The stress which is put upon the steel on the outside will be greatest at the time that the interior layers pass through the critical range, and will not be so marked when the temperature has fallen almost to the atmospheric. It must be remembered also that since the whole piece of steel is being cooled rapidly, the temperature of the outside layer will have fallen to quite a low value by the time that the interior portions have fallen to the temperature of the critical point. This means that the outside layer will have contracted considerably in accordance with the ordinary laws of thermal expansion and contraction, and consequently will feel the effect of the expansion of the internal layers at the critical temperature more than it would if the normal thermal contraction had not taken place. The result of the contraction of the outside and the expansion of the interior will be the exertion of a considerable stress upon the outside layers of the steel, particularly intense at the moment at which the interior part is passing through the critical point.

The stresses set up in the exterior layer during the operations of quenching may be very considerable. There can be no doubt that it is these stresses which are mainly responsible for the production of cracks in various kinds of steel during quenching. It is essential, therefore, that every precaution should be taken to avoid the production of the stresses. Although the actual stress itself cannot be eliminated entirely in any steel which suffers from the mass effect during hardening, it is possible to take precautions to avoid this stress being concentrated or accentuated by the conditions of the surface of the steel.

OBSERVATIONS MADE IN THE HEAT TREATMENT OF ORDNANCE FORGINGS

By Paul E. McKinney

IT IS a notable fact that in the discussion of heat treatment problems most authorities and writers give prime consideration to the question of chemical analysis and finish of material in their study of the material under treatment. The major considerations which are given as the basis for analysis are limited to these points alone with the minimum consideration given to the numerous other factors which have a very material bearing on the subject of heat treatment. Manufacturers of steel know that the analysis of the finished product and the surface condition of the billet or bar of fabricated steel does not tell the whole story as to the quality of the material. Yet the heat treater has not given the fullest consideration to many of these factors which are not apparent from the results of analysis or a general examination of the material but which have a distinct bearing on the serviceability of the finished article and also the behavior of the material under heat treatment.

While the average metallurgist of today has in a large measure abandoned the old beliefs and prejudices which existed in favor of certain brands of steel, it is still well known that with analysis and general surface appearance of the material identical, certain brands of steel are far more satisfactory both from the standpoint of the heat treater, the engineer and the user of the finished product than other brands of identically the same characteristics from the basis of chemical laboratory analysis. There is undoubtedly a reason for the superiority of one brand over the other, based on characteristics due to different methods of manufacture and of handling the material before it reaches the heat treater.

The basis for most specifications for steel touch lightly on many important characteristics but often lay undue stress on chemical analysis prohibiting slight deviations from standard composition, permitting the acceptance as good material of anything which simply falls within the limits of composition and is reasonably free from defects which are apparent to visual examination. Some specifications may have limitations as to discard from ingot or other arbitrary requirements but the science of metal studies has not reached the point where some conditions more fatal than slight deviations in composition are specifically guarded against.

While in the production of molten steel there are only a few processes utilized commercially, the modifications and degrees of refinement of practices in each process as carried out in different commercial plants are innumerable and the gradations in quality of product from various plants are too numerous to mention, the production of some plants presenting certain distinct characteristics as compared with the production from other plants. A general examination of the product from all of these various modifications of steelmaking processes would result in two general classifications of material when based on chemical analysis, namely: Acid and basic steel. Strong opinions exist regarding the superiority of one grade of steel for given purposes over another grade without consideration of the fact that there is well made steel and poorly made steel produced by each process.

A few of the factors which have serious bearing on the quality of

A paper presented before the Washington Chapter. The author, Paul E. McKinney, is chemist-metallurgist, United States Naval Gun Factory, Washington.

steel and which are not apparent from a casual examination of inspection reports of raw material are the following:

Method used in refinement of steel
Metallurgical control of conditions of slag
Methods of introducing ferroalloys, degasifying agents, etc.
Condition of metal previous to tapping from furnace
Temperature of metal during refining and finishing
Size of nozzle used in teeming of ingots
Method of pouring ingots
Size of ingot used for given purpose
Type of ingot used as regards chilling effect, etc.
Rate of speed in pouring ingots
Temperature of metal entering the ingot
Shrinkage of the ingot on cooling
Behavior of the ingot during solidification

Regardless of the process used, the production of steel is based primarily upon the melting of a charge of raw material properly proportioned as regards composition to have sufficient iron combined with carbon, manganese, etc., to produce a boiling action during the early stages of the refining operation, which action tends to refine the crude material as originally melted and to bring it into condition for the succeeding stages in the operation consisting of recarburization and the addition of ferro-alloys to complete the refinement, degasifying the steel and bringing it to the proper composition. Modifications innumerable are introduced into the practice depending upon the results desired for the particular heat, but the prime object is to produce a finished molten bath homogeneous in character and as fully refined as possible. In this discussion we are precluding from consideration entirely such grades of steel as are used for very ordinary commercial purposes and limiting the discussion to such steels as are ordinarily used in the production of forgings and other articles subject to heat treatment.

In the production of large forgings, such as are used for ordnance purposes, many factors entering into the steel melting practices have a very marked influence on the behavior of the material and the ability of the same to withstand the rigid physical tests necessary to insure their serviceability for the purposes intended. The degree of refinement previous to teeming, the temperature of pouring, the conditions under which the steel is poured, the type of ingot, and numerous other factors which might be considered negligible factors in the production of ordinary commercial product most seriously effect the results obtained in the production of ordnance forgings, and with these factors other than normal the heat treater working in the final treatment of such forgings has before him an insurmountable task. Strictly speaking, it is impossible to produce a steel in the molten condition which is so highly refined that no further reaction takes place. Reactions to a limited extent continue in the molten steel up to the time of solidification.

With conditions other than normal as regards refinement in the furnace, high pouring temperature or completion of the reactions between the added ferro-alloys and the molten bath, these reactions taking place in the molten metal during the process of solidification are very pronounced, especially in the case of large ingots which cool at a relatively slow rate. The reactions taking place during solidification of a steel,

N. G. F. 316.

HEAT ON ROOF 67

" " " WALLS 67

" " " BOTTOM 124

MELTER'S REPORT

ELECTRIC FURNACE NO. 1

C. R. Rodgers — MELTER J. J. Jackso

CHARGE AND ADDITIONS.

Material.	Weight.
Nickel steel turnings	6000 lbs.
Chrome nickel steel scrap	8000
ORE 60% Fe	600
MANGANESE, CARBON FREE	
MANGANESE, 80 PER CENT	60
SILICON 50%	60
SILICON FOR SLAG 50%	25
CHROME, CARBON FREE 60%	160
CHROME, 2 PER CENT	
CHROME, 6 PER CENT	
NICKEL	95
VANADIUM	
ALUMINUM	2
	14,737
LIMESTONE	270
LIME	
COKE	
SPAR	20
GRD. ELECTRODE	20
GRD. ELECTRODE, IN LADLE	
	310
DOLOMITE	
MAGDOLITE	600
MAGNESITE	
FIRE CLAY	
GANISTER	
TAR	
MOLASSES	

ANALYSIS.

	C.	Si.	S.	P.	Mn.	Ni.
REQUIRED	.35 .45	.20 .30	Max .050	Max. .050	.40 .60	2.20 2.40
OBTAINED	.43	.21	.033	.034	.50	2.47

PRELIMINARY TESTS.

	TO LAB.	REC'D.	DELAY.							
No. 1	1:10	1:25	15	.26				.024		
" 2	1:40	3:00	1 hr. 20 min.							2.1
" 3	2:15	2:40	25	.34						
" 4	3:20	3:45	25	.40						
" 5					SiO_2	S	P	Mn	Fe	
" 6	Final Slag				29.76	.080	.017	1.61	7.2	

TIME OF HEAT.

Time.		Hrs.	Min.
6:25	PREVIOUS HEAT TAPPED		
8:10	BEGAN CHARGING	1	45
9:20	FINISHED CHARGING	1	10
9:20	CURRENT ON		
12:35	MELTED	3	15
1:25	FINISHED SLAGGING		50
3:20	TAPPED	1	55
	TIME OF HEAT	7	10

ELECTRODE NO. 1 O.K.

ELECTRODE NO. 2 O.K.

ELECTRODE NO. 3 O.K.

SLAG CONDITIONS Dark gray

POURING TEMP. OF STEEL IN LADLE 8 second

POURING CONDITIONS IN MOULDS Normal

HOW STEEL LAID IN MOULDS Quiet

ALUMINUM IN MOULDS None

PHYSICAL CONDITION OF INGOTS Good

METER READING ... NING

METER READING ... MELT DOWN

METER READING A...

TOTAL KWH

KWH PER TON

LADLE NO.

FIG. 1—DATA SHEET OR MELTER'S REPORT WHICH SHOWS COMPLETE HIST

LTER'S REPORT

HEAT NO. X

FURNACE NO. 1 ORDER NO. Y

MELTER J. J. Jackson 1ST HELPER NIGHT DAY DATE April - 1921

	Si.	S.	P.	Mn.	Ni.	Cr.	Va.	Cu.
ANALYSIS								
	20	Max	ax.	.40	2.20	.80		
	30	.050	050	.60	2.40	1.00		
	21	.03	034	.50	2.43	1.14		.28
PRELIMINARY TESTS.								
			024					
					2.12	.56		

	SiO_2	S	P	Mn	Fe
	76	.08	.017	1.61	7.35

PRODUCTION.

No. Ingots.	Size.	Weight.	Per cent.
Butt			
Ladle Skull			
Scrap			
Loss			
Total			
Slag Weight			

Irs.	Mi
1	45
1	10
3	15
	50
1	55
7	10

Current.

Meter Reading Beginning	265300
Meter Reading After Melt Down	268900
Meter Reading at Finish	270800
Total KWH	5500
KWH per Ton	746.27
Ladle No.	2

DELAYS AND CONDITIONS.

Roof Bad

Walls Bad

Bottom Tended to rise during later part of heat.

Electrical Apparatus O.K.

Mechanical Apparatus O.K.

Water Pressure O.K.

seconds

ormal

iet

one

ood

Remarks: Necessary to tap heat before slag was in perfect condition due to trouble with bottom.

4—9-22

OWS COMPLETE HISTORY OF EACH STEEL HEAT MADE IN THE FURNACE

INGOT RECORD.

INGOT NO. Z HEAT NO. X DATE April - 1921 SHIFT 8 to 4

C	P	MN	SI	S	CU	NI	CR									
.43	.034	.50	.21	.031	.28	2.43	1.14									

SIZE OF INGOT 18" x 11'

TYPE OF MOLD Octagonal

EST. WEIGHT 6950 lbs.

MOLD FULL Yes

SIZE OF NOZZLE 1" dia.

TYPE OF HOT TOP Sand

TIME TO POUR 7 minutes

RATE PER MINUTE 993 lbs.

SKULL Heavy

SHRINKAGE 3"

SURFACE CONDITION Fair

REMARKS.

Chrome nickel heat.

Checked and found correct.

John Doe
Asst. Chem. and Met.

4—1639

Richard Roe
Supervisor.

FIG. 2—INGOT RECORD SHOWING SPECIFICATION OF EACH INGOT CAST FROM THE FURNACE

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which is not in perfect condition, will produce the inclusions of metalloids which exhibit themselves during the heat treating operation as so-called ghosts, streaks, slag spots, flakes, woody structure, etc. It is believed that a close analysis of the conditions under which the material is produced will indicate beyond a doubt that such inclusions of metalloids are not due to mechanical impurities entering the ingot from the ladle but are due principally to the results of reactions which produce nonmetallic impurities during solidification. The general tendency of such impurities during forging is to form into different cleavage lines, spots and streaks and, if sufficiently pronounced, will produce a laminated condition with the laminations running parallel to the direction that the material has been forged, rolled or worked. Many alloy steels exhibit the effects of such inclusions to a much greater extent than carbon steels and show this pronounced lamination to an unmistakable degree, this being particularly true in the case of nickel steels or steels containing a rather high percentage of nickel.

The effects of inclusions and conditions due to imperfect melting practices are not noticeable in many grades of commercial steel such as bar stock, where test samples either before or after heat treatment are taken as longitudinal specimens, on account of the fact that the tendency of inclusions after rolling is to elongate themselves in the direction of the rolling. Longitudinal tests on this material will generally exhibit as good values as in the case of normal material, but a different story would be told if tests could be taken transverse to the direction of the rolling.

In the production of ordnance forgings, on account of the fact that the finished forging gets its maximum stress in a tangential direction, it is necessary to take test specimens from the forging in less favorable positions than in the case of commercial bar stock and similar materials, and therefore, the effect of imperfect melting conditions is clearly evident. The mass involved in the average ordnance forging at best defeats the nicety of grain refinement and heat treatment which is possible in forgings of smaller mass and even under the most favorable conditions as regards raw material, it necessarily follows that with disturbing influences, such as nonmetallic inclusions resulting from imperfect melting practices, the difficulties involved are very materially increased.

During the recent war many reputable steel producers experienced expensive failures in the production of ordnance forgings, due to the fact that attempts were made to utilize in the production of these forgings the same general practices as had previously been followed in the production of commercial forgings. Today it is becoming practically universally recognized that the production of a high-grade forging, such as is required for ordnance purposes, cannot be made by the activities of the heat treater alone but starts in the melting furnace, and that without the best raw material, the heat treater cannot perform the impossible feat of remaking the steel. While it is admittedly impossible to definitely specify standard conditions under which each grade of steel is manufactured, it is believed that a careful study by heat treatment engineers of the history of the material from its origin would very materially assist in clearing up many of the difficulties now experienced and that a move in the right direction would be made by the insistence on the part of heat treaters in general of being furnished with data showing the entire

N.G.F. 325

FORGING RECORD.

INGOT NO. 2 DISCARD TOP 30% BOTTOM 5%

SPECIFICATIONS 49-S-2d Alloy #1

SECT.	STUB	DR. AND PC.	NAME OF PIECE	TEMPERATURE AND TIME OF HEATING: CHARGED	TIME	REDUCTION PER CENT: U	E	M	DATE	FORGER AND SUPERVISOR
B-1 to B-25	Z-CH 46	9509-1	Air flask heads	12:30 A.M.	9 hrs. 15 min.	-	160	-	4/25/21	Smith Jones

Numerous transverse cracks developed when ingot was first put under press. These cracks diminished somewhat with additional forging.

4—4609

FIG. 3.—FORGING RECORD SHOWING DETAILS OF FORGING OPERATION AND THE EFFECTS PRODUCED

history of the material. This with a study of the behavior of the same during the heat treatment would within a very short time enable the trade to prepare specifications based on the actual results obtained from materials of varying characteristics.

As an example of the effect of melting conditions on an apparently good heat of steel, the following citation is given in a heat of electric chrome-nickel steel which has shown unusually bad characteristics regarding ability to stand the physical tests, the presence of foreign inclusions and other irregularities in the finished forgings. In this particular heat the analysis of the heat as shown in Fig. 1, would be classed as normal by any heat treater, the finished billets would be classed as acceptable, judging from Fig. 2, and all other requirements of ordinary specifications would be met, yet an examination of the heat record will indicate beyond a doubt that the melting conditions were abnormal in a number of respects, due to a furnace condition which in itself might appear immaterial but actually most seriously effected the final refining of the steel. These conditions would not be apparent to the purchaser of billets in any manner nor to the heat treater who attempted to heat treat the stock after forging and would probably result in one of those cases where heat treatment would be blamed as being faulty. Rejections would be excessive without any apparent cause.

By a study of the conditions which are abnormal in this heat, particularly the condition of the slag and the analysis of the slag, it could be seen readily that the material was at least of questionable quality. With normal melting conditions, the slag analysis should show a manganese content and an iron content not greater than 1 per cent in each case and the condition of the slag should be pure white. While the forging record of this heat, Fig. 3, shows the material to have a tendency to crack during preliminary forging operations, the condition of the finished billets in this case would not have indicated any serious trouble and without an examination of melting conditions, the heat treater would have been at a loss to explain the cause of trouble.

The above example is given for the purpose of demonstrating the possibilities of erroneous deductions which may be made when based on anything but the fullest history of the material. The science of heat treatment will be very materially advanced by the insistence on the part of heat treatment engineers of being furnished with the most complete data on the material which they are handling. It is believed that this is the key to successful heat treatment operations.

THE THERMAL TREATMENT OF CAST STEEL

By Alvin N. Conarroe

THERMAL treatment of steel includes all of the thermal conditions to which steel has been subjected from the time it has been cast until it is ready for shipment. If this treatment has been done wisely, the steel will be in the best condition to give good service under the widely varying conditions to which it is subjected in use. Since most steels are cast in some form before subsequent treatment, any defects or conditions inherent to this procedure are more or less reflected in the finished product. Thus, the subject of cast steel might be made to cover a wide range, but in this article will be limited to those steels cast initially to their final form, and, since a large majority of steel castings are made of medium carbon steel, mainly to hypoeutectoid steel.

Steel is essentially an alloy of pure iron, a ferrite, and a definite chemical compound of iron and carbon, cementite. Therefore, as the percentage of carbon increases, the amount of cementite increases up to the maximum solubility of carbon in iron at normal temperatures, which is about 1.7 per cent carbon. When steel in the liquid state solidifies, it forms a solid solution, or alloy. This solid solution is termed austenite and is homogeneous in character just after solidifying. As the percentage of carbon increases the temperature at which solidification takes place is progressively lowered, following in this respect the general law of eutectic solutions. This progressive lowering of the freezing point is continued until the carbon content has reached 4.3 per cent, when it rises again. However, this per cent of carbon has extended into the field of cast irons, to the eutectic ratio and is of no concern in the present discussion. As the solid solution of iron carbide in iron cools further, certain changes or transformations take place which are manifested by evolutions of heat at certain temperatures, causing a lag or break in the cooling curve of the material. The temperatures, at which these changes occur, are called critical temperatures and a proper understanding of their cause and position is important to the intelligent heat treatment of steel. All plain carbon steels, containing up to 0.35 per cent carbon, have three critical points; those from 0.35 per cent carbon to 0.85 per cent carbon, two; 0.85 per cent carbon steels show but one point, while those above 0.85 per cent show two points of transformation. These points are referred to as Ar_3, Ar_2, Ar_1, $Ar_{3\text{-}2}$, $Ar_{3\text{-}2\text{-}1}$, $Ar_{3}cm$, $Ar_{2\text{-}1}$, the "A" meaning a point of transformation and "r" coming from refroidessement, meaning cooling.

In a similar manner to the lowering of the solidifying point with increasing carbon content, the two upper critical points are lowered as the carbon increases, reaching a minimum and coinciding with the lower critical point at 0.85 per cent carbon, rising again with increase of carbon content. On account of the similarity of these transformations in the solid solution to the freezing of eutectic solutions, those steels containing 0.85 per cent carbon have been called eutectoid steels, those containing less carbon, hypoeutectoid, those containing more carbon, hypereutectoid. Eutectoid steel consists of but one microconstituent, when examined under the microscope, and it appears as grains containing alter-

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A paper prepared for the Philadelphia Convention. The author, Alvin N. Conarroe is chemist, National Malleable Castings Co., Melrose Park, Ill.

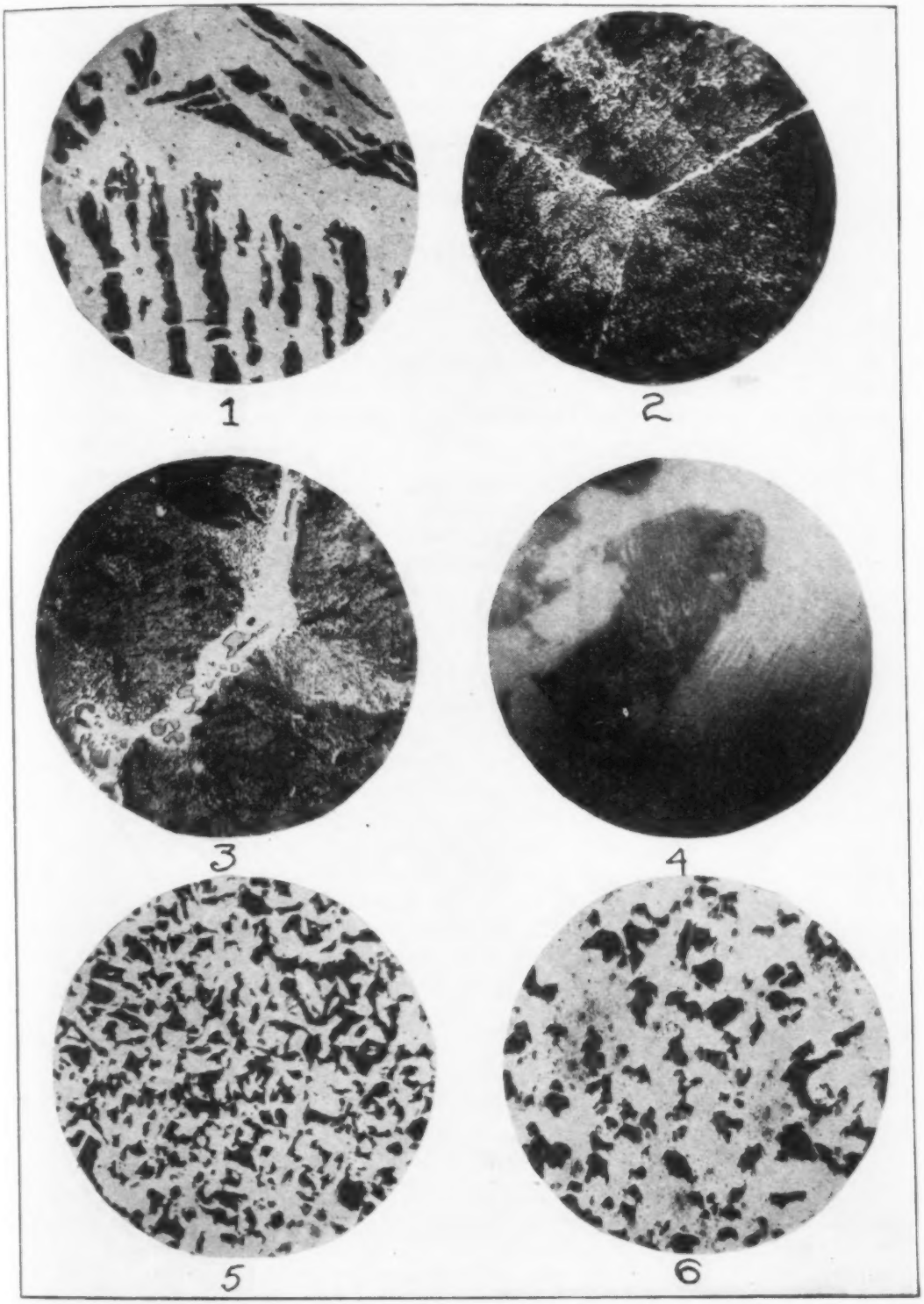

Fig. 1—Unannealed hypoeutectoid cast steel. X 50. Junction of two allotrimorphic crystals showing deposition of ferrite along cleavage lines of crystalline grains. Fig. 2—Ingot structure of cast steel approaching eutectoid composition. X 100. Junction of three large crystalline grains showing thin white ferrite lines marking grain boundaries. Fig. 3—Steel same as in Fig. 2 but cut from a segregated section. X 100. Shows broad ferrite band between grains, inclosing islands of manganese sulphide and manganese silicate. Also shows laminated structure in parts of pearlite areas, indicating segregation of eutectoid material. Fig. 4—Pearlite of hypoeutectoid steel X 950 showing laminated structure. Fig. 5—Underannealed hypoeutectoid steel X 100. Although the ferrite and pearlite are well distributed, ferrite still retains pointed needle structure resulting from incomplete absorption. Fig. 6—Overannealed hypoeutectoid steel X 100, showing structure resulting from overheating and cooling slowly past critical range. Sufficient time has been given for migration of ferrite to grain boundaries.

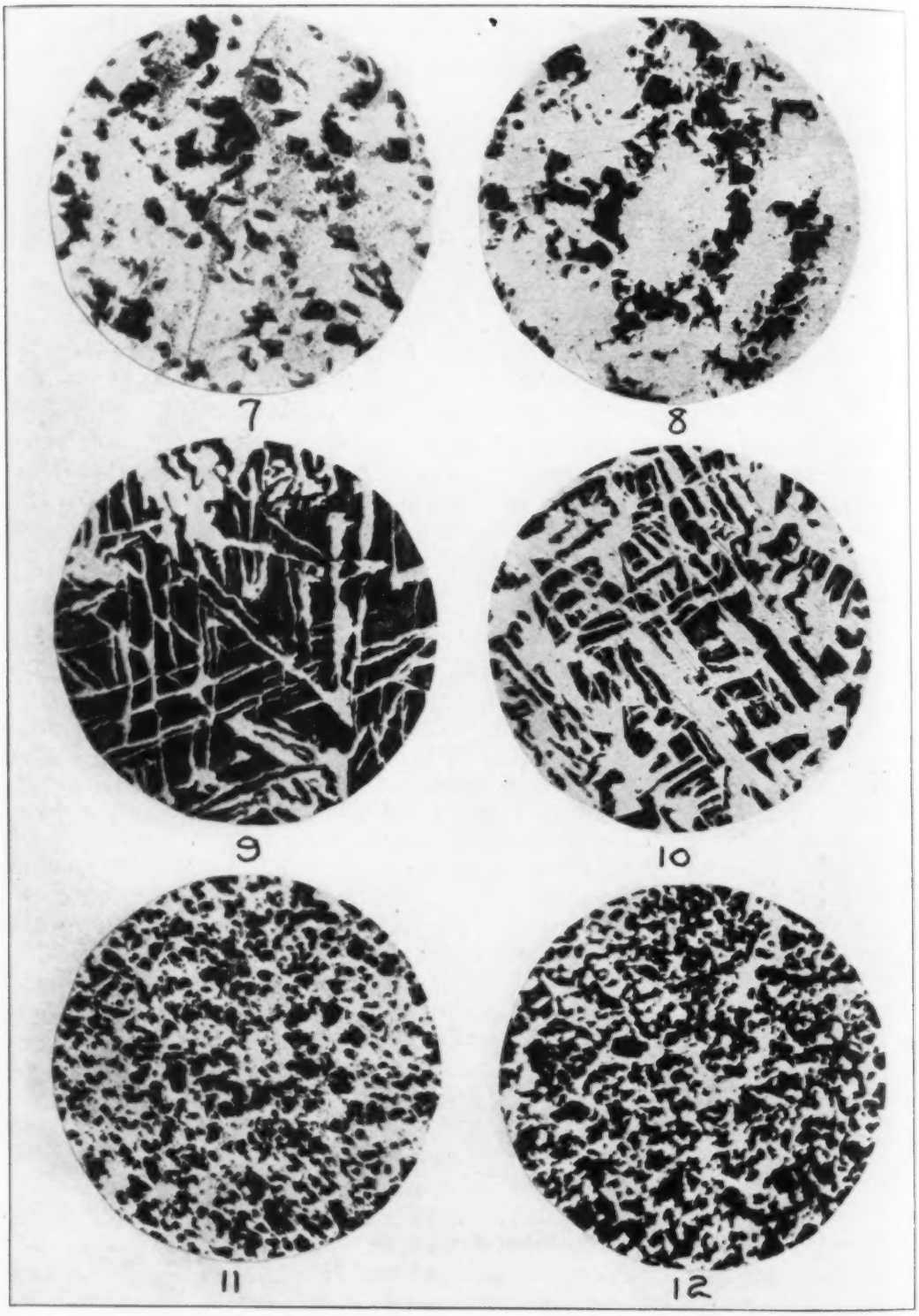

Fig. 7—Same condition shown in Fig. 6, however, metal has been strained before heating. X 100. Fig. 8—Structure developed by prolonged heating at fairly low temperature, within critical range, slow cooling. X 100. Note rounded appearance of ferrite, probably resulting from surface tension in ferrite plates. Fig. 9—Hypoeutectoid steel overheated and quickly cooled in air. X 100. Widmanstatten structure. Ferrite has been unable to migrate to grain boundaries and is partially deposited along octahedral cleavage planes. Fig. 10—Same condition shown in Fig. 9. X 100. Here most of intersections form quadrilaterals while most of former were triangular. Both are true intersections of octahedral. Fig. 11—Well annealed hypoeutectoid steel. X 100. Note even distribution of ferrite and pearlite also small size of pearlite grains. Fig. 12—Another well annealed specimen slightly higher in carbon content. X 100.

nate laminations of iron and iron carbide. This has been called pearlite on account of the similarity of its appearance to mother of pearl. When the percentage of carbon is below the eutectoid ratio, the metal consists of iron, or ferrite and pearlite, when slowly cooled to normal temperature; when above that ratio, it consists of cementite and pearlite. Steel in the molten state is nonmagnetic and when cooling after solidifying, remains in this state until the second critical point is reached, when it again becomes magnetic. This fact, together with the marked dilatation of the metal as it passes through the third critical point has led to the conception of allotropy in iron, an allotropic form being defined as having the same chemical constitution but different physical properties, either in crystalline form, magnetic properties or thermal expansion. Thus hypoeutectoid steel above the third critical point is said to consist of a solid solution of gamma iron and carbon. Between the third and second critical points it consists of beta iron and carbon, and between the second and first critical point, of alpha iron and carbon.

As slowly cooling, molten, hypoeutectoid steel reaches the point of solidification, the molecules arrange themselves in the form of small crystals at various points throughout the molten solution. These act as nuclei for further deposition of small crystals on further cooling of the molten metal, and a solid ground mass gradually develops throughout the molten material, which finally becomes entirely solid, when the solidus is reached. Manifestly, since the axes of these small crystals are arranged in different directions, the planes of cleavage of the resulting grains, or allotrimorphic crystals, will have different directions. Since these grains have true crystalline planes of cleavage, but cannot take the crystalline form due to interference, they have been called crystalline grains and the cleavage lines are said to represent the orientation of the crystal. Also, since it is conceivable that the small crystals will continue to deposit about their various neuclei until there is no longer room for further deposition of a complete crystal between the various allotrimorphic crystals, there must remain a small amount of metal which cannot crystallize and must, therefore, remain in the amorphous condition. Rosenhain claims that this amorphous metal acts as a cement between the crystalline grains, thus accounting for the fact that rupture is nearly always transcrystalline instead of intracrystalline. The crystalline nature of the grains of steel is supported by studies of the effect of straining metals beyond their elastic limit, thus giving rise to slip along the cleavage planes. From these studies it has been shown that iron in the gamma state crystallizes in octahedral or duodecahedral forms, while beta and alpha iron take the form of cubes.

Since metal in cooling cools from the outside inward, the deposition of crystals begins on the outside and extends inwardly. Thus the crystalline growth normally would be by layers progressively, but sometimes under slow cooling conditions a pine-tree growth is set up by the linear deposition of crystals, normal to the cooling surface. This growth has been called a dendrite and such steel is said to be dendritic. Since all steels normally contain impurities, such as phosphorus, sulphur, and manganese, these impurities would be deposited in the form of impure segregates during the solidification of such a crystal growth. Phosphoritic metal is particularly prone to dendritic segregation, especially when slowly cooled.

As hypoeutectoid steel cools after solidification, no change takes

place until the critical range is reached, beginning at Ar_3. Upon passing through this point, granulation begins and the excess substance or solvent, ferrite, begins to separate out. If the cooling is sufficiently slow, the ferrite migrates to the grain boundaries, if not, it is partially deposited along the cleavage planes, the latter being the usual case with steel castings. As the metal further cools, ferrite continues to separate until Ar_1 is reached, at which point a change takes place in the austenite grain, which is now entirely transformed into pearlite. The temperatures at which these changes take place depend upon the composition of the steel and rate of cooling, certain elements causing a lowering of the critical point, and quick cooling considerably depressing it. Manganese and nickel are particularly active in depressing the lower critical point and, when present in large amounts, even depress it below the atmospheric temperature. These steels are, therefore, austenitic in character, since they never reach the lower critical point in nomal cooling.

Upon reheating steel, which is pearlitic, no change takes place until the lower critical point is reached, when an absorption of heat takes place and the pearlite is transformed into austenite. The point at which this occurs is considerably higher than the corresponding point on cooling, the difference being due to hysteresis and dependent upon the chemical composition of the material. As the temperature rises further, a gradual absorption of ferrite into the austenite grain takes place and the coarse grain structure is slowly broken up until the critical range is passed. The steel again becomes nonmagnetic on passing the second critical point upwards and, upon passing the third critical point, is again a homogeneous solid solution, providing the heating has been sufficiently slow for the completion of the reactions. The points at which these changes occur have been called Ac_1, Ac_2, Ac_3, $Ac_{2\text{-}3}$, $Ac_{1\text{-}2\text{-}3}$, $Ac_{1\text{-}2}$, Ac_3cm; "A" meaning as before a transformation point, and "c" coming from chauffage, meaning heating. If the steel is now allowed to cool slowly, a new granulation begins and on passing Ar_3, ferrite begins to separate as before along the new grain boundaries.

If the temperature to which the steel has been heated is considerably above the critical range and cooling is sufficiently slow, granulation develops rapidly and large pearlite grains develop through changes in orientation of the small crystals. On further cooling, ferrite again separates and migrates to the grain boundaries if cooling is sufficiently slow. If the rate of cooling is accelerated, however, on passing the granulating range, the ferrite cannot migrate to the grain boundaries, but is deposited along the cleavage planes of the austenite grain, giving rise to the familiar Widmanstatten structure, so common to air cooled castings which have been overheated. Since this deposition is along cleavage planes, studies of the angles of intersection have given much information regarding the system of crystallization to which the allotrimorphic crystals belong. Further slow cooling results as before in the deposition of more ferrite until the lower critical point is reached, when austenite is again changed into pearlite.

Up to this time, metal cooling slowly from above the critical range has been considered. If the rate of cooling is accelerated by quenching, time is not given for the completion of the deposition of the excess ferrite and this remains dissolved in the austenite grain in varying proportions, depending upon the rapidity of the fall in temperature. If the cooling has been very rapid, most of the ferrite is in solution and

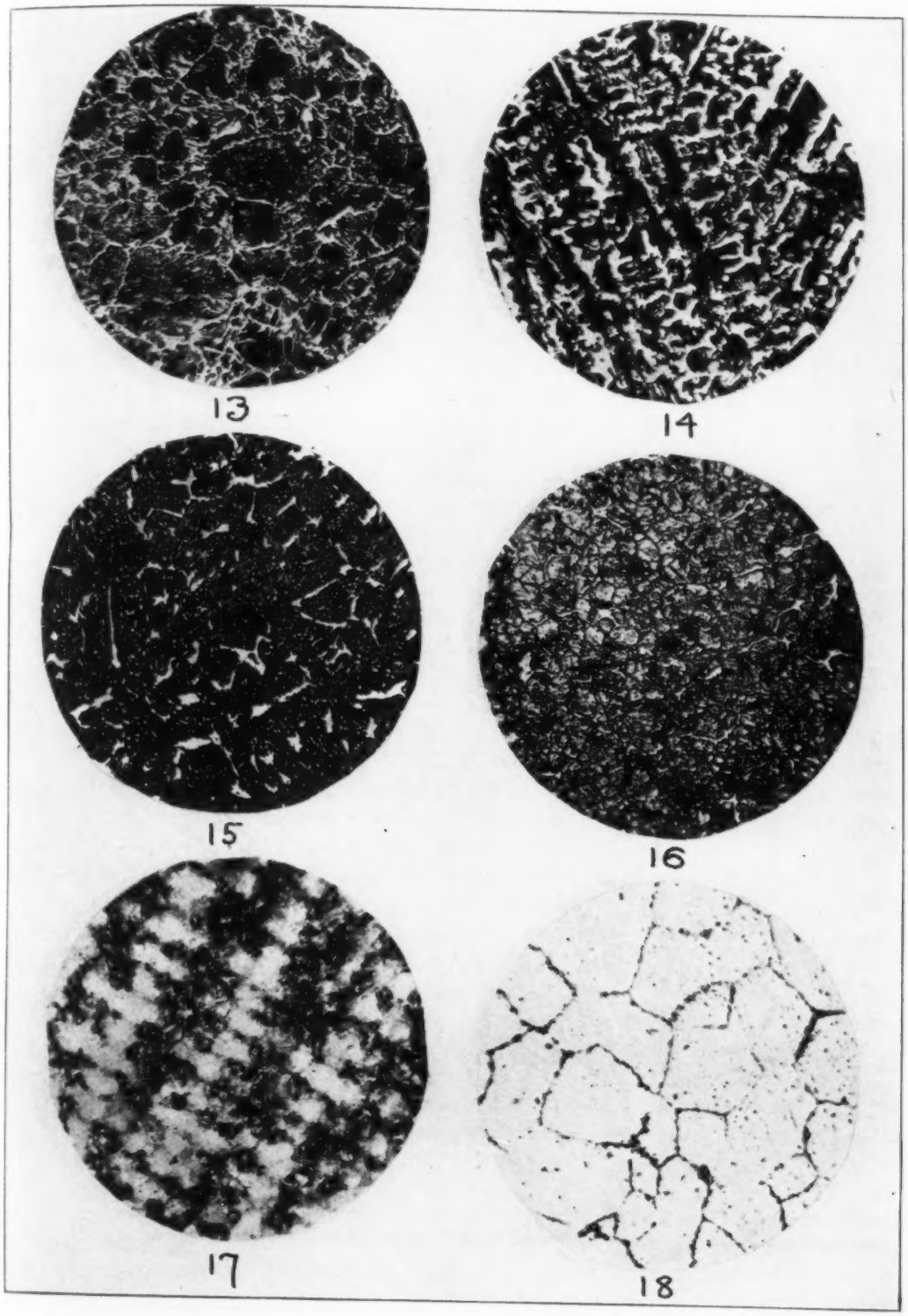

Fig. 13—Structure developed by quenching hypoeutectoid steel. X 100. Note thin ferrite lines surrounding sorbitic grains. Fig. 14—Hard iron as cast. X 100. Shows dendritic structure. Hypereutectoid material, the excess substance being cementite. Fig. 15—Hard iron heated partially through critical range and quenched. X 100. Shows partial absorption of cementite. Fig. 16—Hard iron heated to near solidus and quenched. X 100. Note almost complete absorption of cementite and martensitic nature of material. Fig. 17—Dendritic structure resulting from linear deposition of crystals normal to cooling surface. X 100. This specimen was highly phosphoritic. Fig. 18—Same material as shown in Fig. 17, but properly treated to eliminate dendritic structure. X 100.

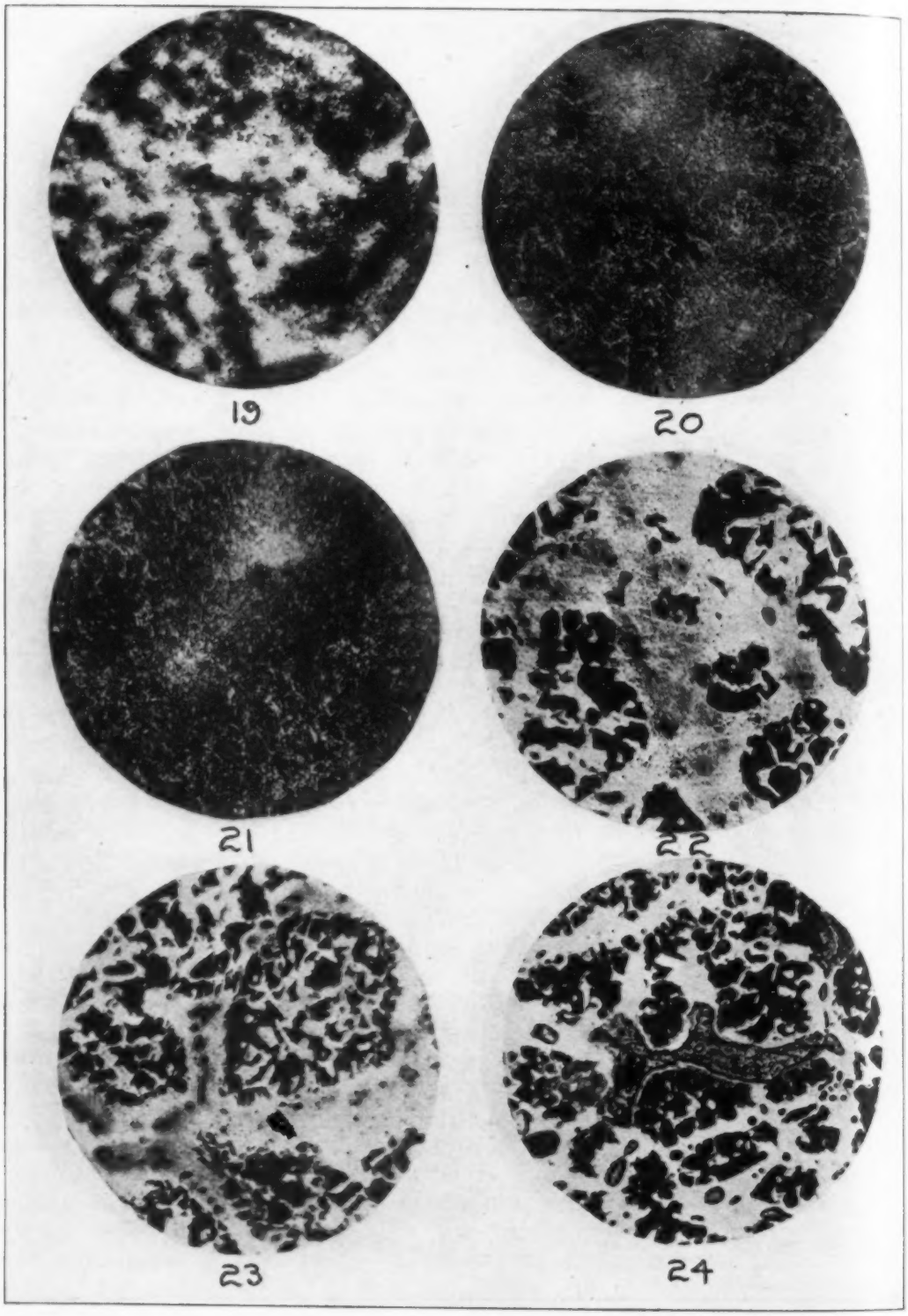

Fig. 19—Radial dendrites developed normal to a curved surface. X 100. Fig. 20—Ghosts. Specimen has been quenched but previous heating has not completely broken up dendritic structure which appears as faint, hazy spots. X 100. Fig. 21—More ghosts. These have been developed in a region containing cavities due to occluded gases. X 100. Fig. 22—Ferrite plating caused by presence of sonims. Annealing has not caused the ferrite plates to go into solution. X 100. Fig. 23—More sonims surrounded by ferrite plates. X 100. Slag inclusions have formed nuclei for deposition of ferrite. Fig. 24—Sulphides and silicates of manganese surrounded by ferrite envelopes. X 100.

the metal is hard and brittle. In this condition it is said to be martensitic. If martensitic material is reheated slightly, part of the ferrite is liberated and the hardness diminishes. The metal then becomes troostitic in character. Still further heating liberates more ferrite and it is found that the austenite grain has become amorphous in structure. This is the sorbitic condition and is the most desirable, where high tenacity combined with ductility is desired. Further heating up to the critical point again leaves the steel in the pearlitic condition, which is the regular annealed state and gives the highest ductility.

The annealing of steel castings for proper physical properties is complicated by the fact that no work is done on the plastic material, which would assist in the breaking up of the crystalline grain structure, which must be entirely eliminated by heat treatment. The result is that castings require a higher temperature and longer time to accomplish this. Thus a proper anneal would require that the castings be slowly heated to a point considerably above the critical range and held long enough to insure the penetration of the heat to the center. This, of course, is regulated by the thickness of the section, and since most castings have variable sections, heating must be regulated partly by the thinnest section, which will be put under strain when a single anneal is desired. By proper regulation of the temperature-time functions excellent results can be accomplished with a single anneal, but where the sections are varied, it is obvious that the lighter sections become overtreated before proper treatment has been accomplished in the heavier. In cases of this kind the proper course is to give a double anneal, first heating to a fairly high point to refine properly the heavy section, and then cooling below the lower critical point and reheating to a lower temperature to break up the secondary structure set up in the thin sections. In anneals of this type, a fairly rapid cooling through the granulating range, followed by slow cooling past the lower critical point, is advantageous on account of the finer grain structure generated.

Thus far only pure carbon steel has been considered in our discussion. However, all steel contains to a more or less degree certain impurities which are inherent to the method of manufacture. These impurities consist of gases, which remain dissolved in the solid metal, called occluded gases; particles of slag from the bath or refractories; and reaction products of the deoxidizers used in the bath and ladle, called sonims.

When steel is in the molten state, it has a great solvent power for the gaseous products of the furnace reactions and thus contains quantities of carbon monoxide, nitrogen, oxygen, and some hydrogen in solution. When the steel solidifies, its solvent power decreases and these gases when present to marked degree, are liberated to a certain extent, forming cavities or blow holes in the pasty metal. Certain elements, such as manganese, aluminum, silicon, and titanium, when added to steel, either react with these gases to form compounds which pass away into the slag, or increase the solubility of the steel for these gases. When present in sufficient quantity to form considerable blowiness, these gases seem to exert a local depressing effect upon the critical point of the steel, thus causing overtreatment of these areas when given the usual heat treatment. This results both through their depressing effect and the cutting down of the area of the section. The presence of these gases in excess leads to excessive shrinkage with all of its evils due to piping and

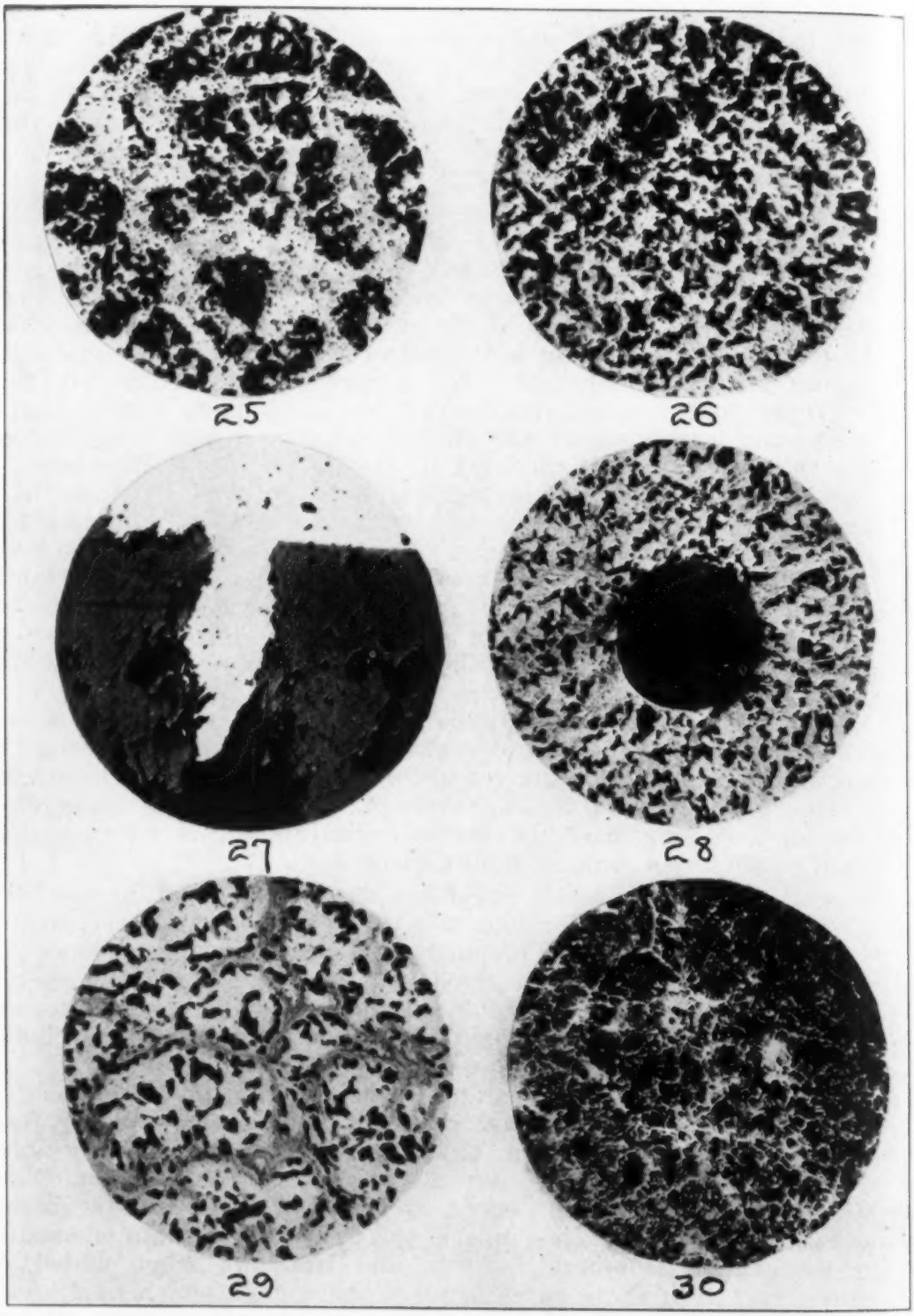

Fig. 25—Persistent ferrite segregation caused by numerous small slag particles. X 100. Fig. 26—Same material as in Fig. 25 but containing few sonims. X 100. Note even distribution of ferrite and pearlite. Fig. 27—Silicate of manganese inclusion at edge of cavity. Unetched X 100. Note slate gray color of inclusion. Fig. 28—Silicate of manganese inclusion. X 100. Metal has solidified about semimolten material causing it to become spherical in shape. Fig. 29—Slag inclusions along grain boundaries. X 100. Typical of ferrous sulphide inclusions. Fig. 30—Quenched material containing sonims. X 100. Note persistent nature of ferrite envelopes which show as thin white envelopes surrounding sonims in sorbitic background.

cracking, where heavy and light sections join. The steel is then generally spoken of as oxidized metal. It is found generally that where excessive shrinkage occurs, small hair-like cracks are developed radiating outward from the pipe. With proper annealing these are sometimes eliminated, but if the pipe has an opening to the atmosphere, which occurs in most cases, the surfaces of these cracks become oxidized and they cannot be eliminated. Many times it is found that the area immediately surrounding a pipe is decarbonized, due to the action of the oxygen of the air drawn into the pipe upon the carbon in this area. These cracks and decarbonized areas have a localized weakened condition, and while benefited by heat treatment, are never completely eliminated. This condition is properly a furnace and foundry condition and should be eliminated there.

The slag inclusions and reaction products of the "deoxidizers" have been called sonims, the word being derived from the expression "solid nonmetallic impurities". The churning action of the bath when boiling and of the metal when running into the ladle, causes a mixing of small globules of the slag and reaction products with the steel. These consist of sulphide of manganese, probably containing some ferrous sulphide, iron silicates, manganese silicate, and, where aluminum is used as a deoxidizer, of aluminum oxide.

If the metal is not sufficiently fluid, or if sufficient time is not allowed, these inclusions cannot rise to the surface with the main body of the slag, but remain suspended in the molten metal as semisolids, due to their higher melting points, and are carried with the stream of metal into the castings, where they form solid inclusions in the metallic section. These inclusions have very little strength in themselves, and thus act much as cavities in reducing the strength of the section. However, the role played by these inclusions does not stop with the cutting down of the sectional area, but it has been demonstrated that they probably promote a segregation of ferrite about themselves during the cooling from above and through Ar_3. These inclusions are always found surrounded by ferrite, even when located inside pearlite grains. These ferrite segregations form a ductile, weak spot and give rise to the faint, hazy appearing spots called "ghosts" appearing upon a polished and etched specimen, especially when complicated by dendritic structure, caused by phosphorus segregation. A dendritic structure resulting from phosphorus segregation can be eliminated by prolonged exposure to a high temperature, followed by quick cooling, preferably quenching.

On the other hand, ferrite segregation caused by sonims is very persistent and, while partially absorbed by prolonged heating to a high temperature, still shows a ferrite envelope surrounding the sonims, even in quenched specimens. The sonims, likewise, are unaffected in shape by heat treatment, and since they probably belong to the same system of crystallization as alpha iron, offer good nuclei for segregation of ferrite. Some experiments by Mahin have led him to think that ferrite segregation is promoted by a partial solution of the inclusion in the surrounding metal, thus hastening the rejection of the ferrite through the law of solubility. Manganese sulphide and iron sulphide are frequently found where shrinkage cracks occur and probably promote the formation of shrinkage cracks, due to the formation of intracrystalline films.

Steel castings often show slight defects which are removed by weld-

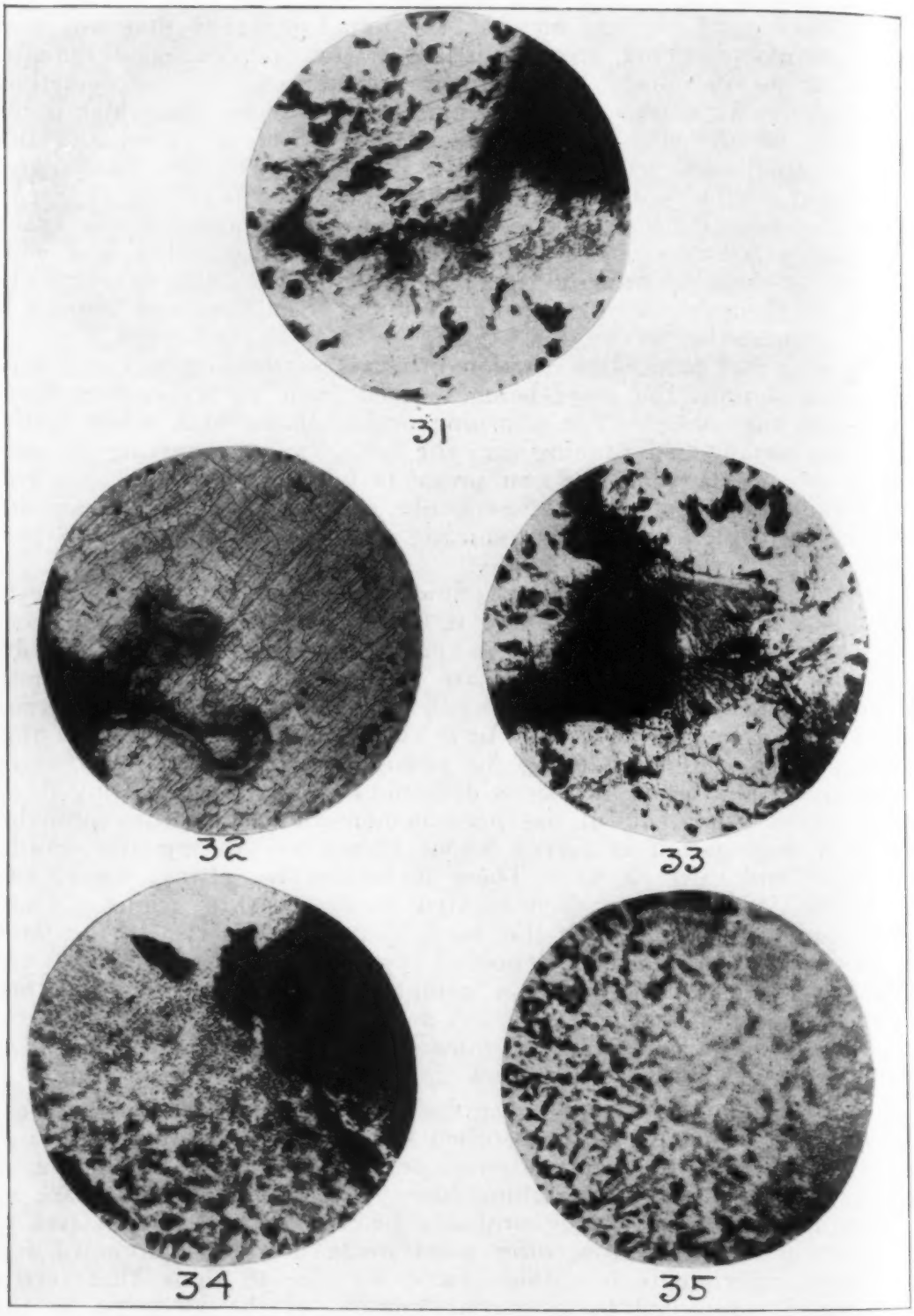

Fig. 31—Junction of a "scab" to main body of metal. X 100. Note crack extending into main body from point of junction. This acts much as a notch when put under stress. Fig. 32—Shrinkage cavity surrounded by a decarbonized area. X 100. Air drawn into cavity has oxidized carbon in surrounding material. Fig. 33—Area adjoining a shrinkage cavity showing fine hair-like cracks extending outward from cavity. X 100. Stress applied to material has caused slip along one of these cracks with resultant rupture and distortion of moving grain. Fig. 34—Improperly made weld showing cavity containing foreign inclusions. X 40. Also note gradation of structure from carbonless iron to overheated structure of normal steel. Fig. 35—Properly made weld. X 40. Note smoothness of shading from carbonless iron to normal steel. Overheated structure shown leaves no doubt that welded castings should be reannealed.

ing. These are generally in the nature of small cavities or cracks. The welding is accomplished usually by causing the metal surrounding the defect to assume the liquid state, through the use of the electric arc or oxyacetylene torch, and flowing into it sufficient low carbon rod to fill the defect. Manifestly, the steel in this region is in the coarse, crystalline state of unannealed castings and should be refined by annealing. In cases of this kind an anneal which would increase the notch toughness of the material should be beneficial. Fairly quick cooling, so as to prevent the complete formation of lamellar pearlite, increase notch toughness, which is greatest when the steel is sorbitic.

In concluding it may be said that steel castings can be refined by heat treatment to possess physical characteristics comparable to forgings, but longer and more drastic treatment is required. Defects inherent to cast steel are more pronounced in castings due to lack of mechanical working. Foreign inclusions have a marked influence upon the strength of the steel casting, due to their segregating influence upon ferrite. The rate of cooling of castings after pouring exerts an influence upon the size of the crystalline grains and especially upon material which has a tendency to formation of dendrites. Dendrites can be eliminated by heat treatment, but require drastic treatment. Shrinkage should be eliminated in the furnace and foundry practice. Welded castings should be reannealed to remove strains and to properly refine the grain.

THERMAL AND PHYSICAL CHANGES ACCOMPANYING THE HEATING OF HARDENED CARBON STEELS

By Howard Scott and H. Gretchen Movius

WIDESPREAD interest which has been expressed recently in the properties of steel in the "blue-heat" range and in the subject of "temper brittleness" makes it highly desirable to study in detail the transformations in steel below the A_1 change. In a previous paper[1] the authors have pointed out certain thermal characteristics of the magnetic change in cementite as observed in annealed steels by means of thermal analysis. In this paper the subject under investigation is the thermal change observed in hardened steels on heating below Ac_1.

Outside of the possible bearing of such information on the low-temperature properties mentioned, there remains the desirability of establishing fundamental characteristics of steel. The one in question is of particular value in that it may furnish a practical basis for defining the natural boundary between martensite and the troostite of tempering, which from present information is very indefinite.

A survey of the changes in some of the physical properties of carbon steels on tempering would, on account of certain inconsistencies, lead one to doubt the existence of a sharp demarcation between the constituents—martensite and troostite. Heating curves of hardened steels, however, have shown a well-marked heat evolution ending around 300 degrees Cent. Such heat evolution would be expected from the usual conception of the formation of martensite; namely, that one or more of the transformations occurring on slow cooling are suppressed by quenching. The consummation of the suppressed transformation, or transformations, is a manifestation of the completion of the constitutional change, and, therefore, evidence of a boundary between two constituents, presumably martensite and troostite. Whether the end of this heat evolution should be used to define those constituents the future will decide; the present work seeks only to establish its nature in a variety of carbon steels and its relation to accompanying changes in some of the physical properties.

In the literature some work has appeared on this heat evolution in hardened carbon steels. Osmond [2] and Maurer[2] have given inverse-rate heating curves; Heyn and Bauer[3] and Portevin[3] have given differential curves showing the phenomenon.

The temperature values for the transformation are somewhat higher than those obtained here. In general, the curve inflections are neither prominent enough nor the statement of operating details sufficient to allow of a precise definition of the transformation characteristics. Also the effect of important variables has not been determined. This phenomenon has been observed also by continuous measurement of the changes in some physical properties on heating. Grenet[4] detected an inflection in the expansion and electric-resistance curves of a high-carbon steel, Chevenard[5] in expansion curves, and Honda[6] in magnetic-induc-

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1 Chemical and Metallurgical Engineering, **22**, p. 1069; June 9, 1920.
2 Osmond, J. Iron and Steel Inst., p. 38; No. 1, 1890. Maurer, Rev. de Met., **5**, p. 711; 1908.
3 Heyn and Bauer, J. Iron and Steel Inst., **79**, p. 109; 1909. Portevin, de Met., **13**, p. 9; 1916.
4 Grenet, Rev. de Met., **1**, p. 353; 1904.
5 Chevenard, Rev. de Met., **14**, p. 610; 1917.
6 Honda, Sci. Reports Tohoku Imp. Univ., **6**, p. 149; 1917.

tion curves. The magnetic curves are the only ones which seem to follow closely the progress of the heat change. Brush[7] has made extensive observations on the heat evolution at ordinary temperatures in recently hardened steels. He noted a heat evolution, greatest immediately after

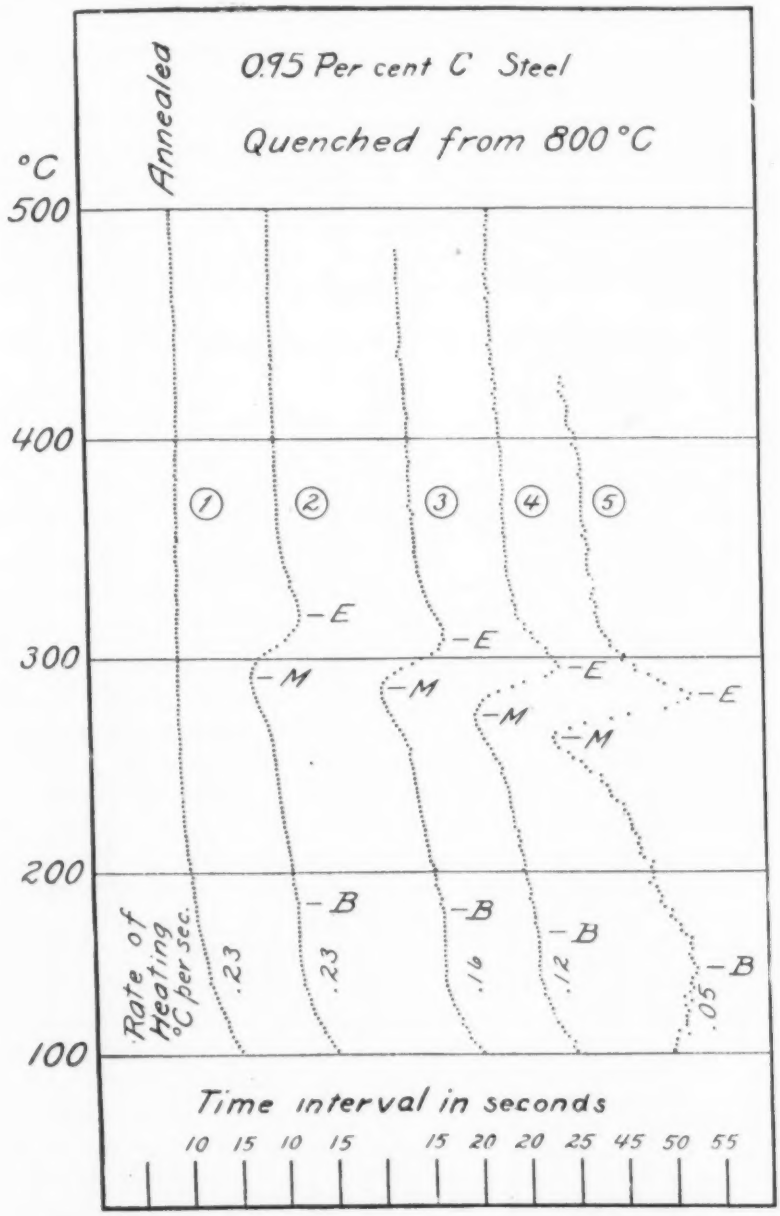

Fig. 1—Inverse rate heating curves of hardened steel, showing effect of rate of heating on Ac

hardening, gradually diminishing in rate with time and becoming imperceptible after several weeks. The physical changes accompanying this spontaneous evolution were very small in comparison with those accompanying even slight tempering.

While the present research is confined to carbon steels because of

7 Brush, Bull. A. I. M. M. E. No. 153, p. 2389; 1919.

their fundamental importance, it is being extended to alloy steels in order to obtain further light on the effect and function of the alloying elements.

The inverse-rate method of obtaining thermal curves has been used at the Bureau of Standards as the most effective and satisfactory method for studying the transformations in steel. Used in connection with the

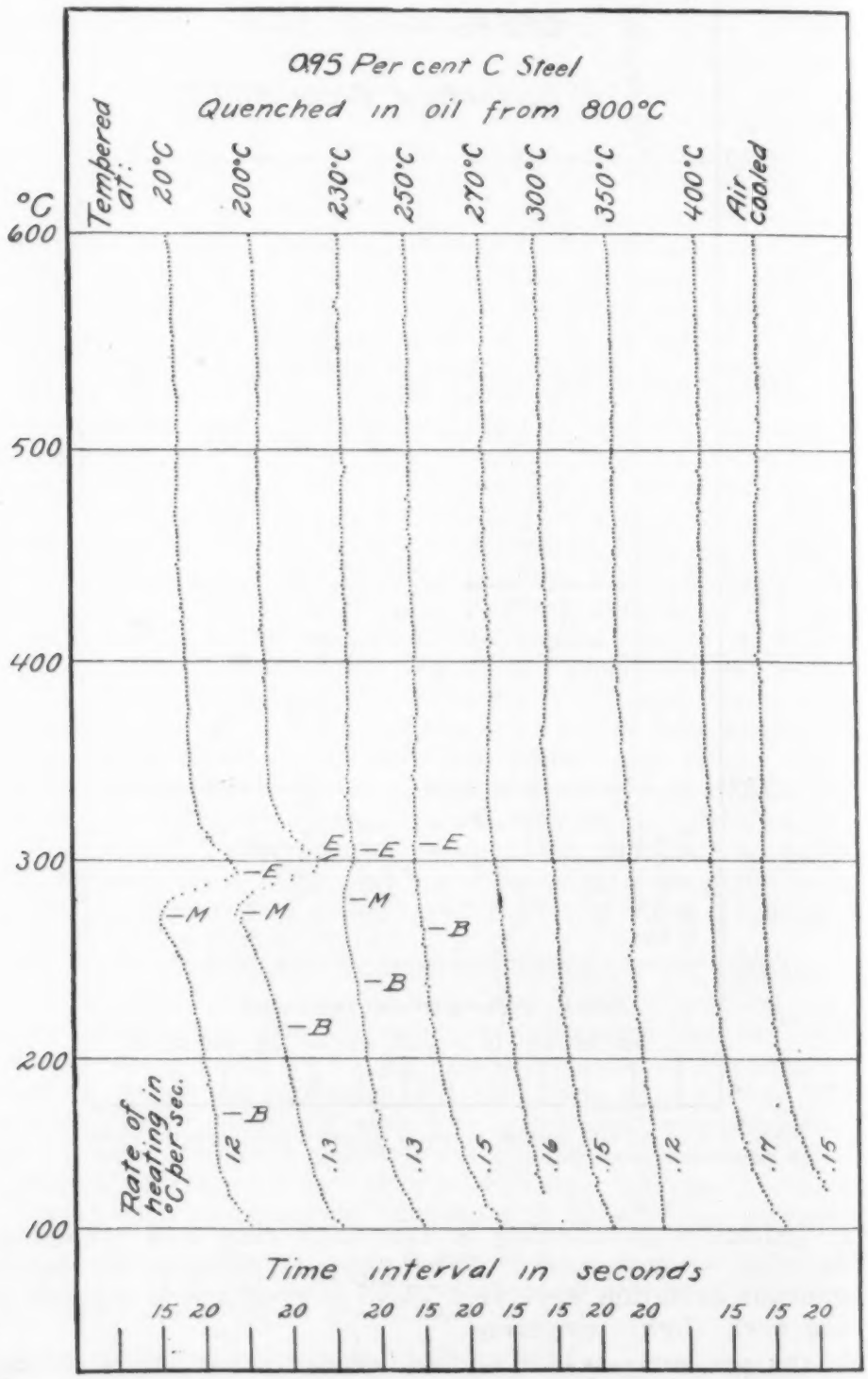

Fig. 2—Inverse rate heating curves of hardened steel, showing effect of previous tempering for 30 minutes on Ac_1

apparatus already described[8] excellent curves can be obtained at the low temperatures where the heat evolution under examination is found. The details of mounting size of sample, and operation are given in the above reference. A temperature interval corresponding to 20 microvolts on a platinum, platinum-rhodium thermocouple was used in this investigation.

The materials studied were seven steels of the compositions given in Table I. Heating for quenching, as noted on the curves and in the tabulated results, was carried out on the prepared samples by introduction into an electrically heated alundum-tube furnace wound with resistance wire. Charcoal was present to reduce oxidation, and a platinum, platinum-rhodium thermocouple was used for the measurement of temperature. In tempering, the specimen was heated 30 minutes in an oil or

Table I

RESULTS OF CHEMICAL ANALYSES OF STEELS INVESTIGATED

Carbon Per cent	Manganese Per cent	Silicon Per cent	Phosphorus Per cent	Sulphur Per cent
0.40	....	0.01	....	....
.44	1.00	.02	....	....
a .46	.35	.06	0.02	0.05
a .73	.38	.01	.04	.05
.95	.22	.24	.02	.01
1.01	....	.01	....	.005
1.94	....	.01	....	.005

a Furnished by courtesy of Carnegie Steel Co.

nitrate bath, as required by the temperature. Temperatures below 300 degrees Cent. were measured with a mercury thermometer.

All samples of the quenched 0.95 per cent carbon steel not receiving subsequent tempering were run within from one to three days after quenching. All the other steels not tempered were run within from 6 to 16 days after treatment, excepting the 1.01 per cent carbon and 1.94 per cent carbon steels, which were run the day following treatment.

The principal phenomenon under consideration here, the heat evolution on heating hardened carbon steels, will be designated as "Ac_t," a notation used by one of the authors[9] for the same phenomenon in a high-alloy steel.

The thermal curves, taken to show the effect of several variables on the transformation Ac_t, are shown in Figs. 1, 2, 3, 4, and 5. For the reduction of the thermal-curve data to tabular form, the temperatures of the principal curve bends caused by the Ac_t transformation were taken as denoted on the curves by B, M, and E, beginning, maximum, and end, respectively. The rate of heating given is that just before the beginning of the transformation. The values in the column of Table II marked "Intensity" represent the difference in seconds between the time at the maximum and at the end of Ac_t, except in the case of the austenitic steel, where they represent temperature drop.

The temperature of the maximum of Ac_1, maximum temperature before decalescence when that phenomenon was observed, is also given, but the heating curves are not plotted to show Ac_1, in order to avoid excessive reduction of the curves on reproduction.

Rate of heating has a considerable effect on the temperature and form of Ac_t for the comparatively fast rates required by thermal analysis,

[8] Scott and Freeman, Bull. A. I. M. M. E. No. 152, p. 1429; 1919. Also B.S. Sci. Papers, No. 348.
[9] Scott, Bull, A.I.M.M.E. No. 146, p. 157; Feb., 1919. Also B.S.Sci. Papers, No. 335.

as may be seen from the curves of Fig. 1, which were taken on the 0.95 per cent carbon steel. The principal data taken from these curves are plotted with rate of heating as the abscissas, in Fig. 6. It will be noted from this figure that the temperature characteristics of Ac_t for zero

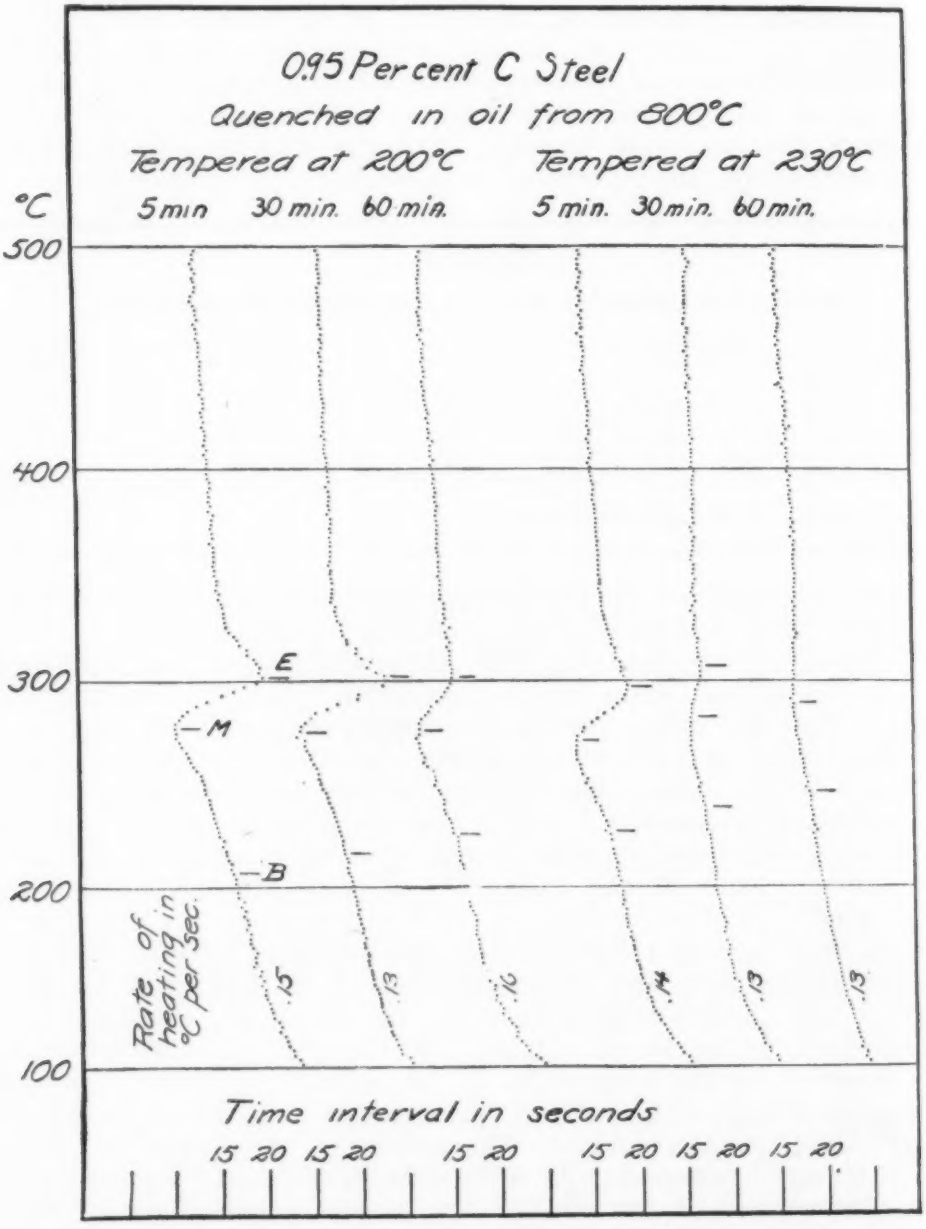

Fig. 3—Inverse rate heating curves, showing effect of duration of previous tempering on Ac_t

rate are 155, 250, and 260 degrees Cent., respectively for the beginning, maximum, and end of the transformation. This appears to represent the progress of the transformation for a tempering time approximating nomal tempering conditions, probably about 30 minutes. From the

sharpness of the beginning of the transformation it would appear that the quenched steel is the equivalent of a steel instantaneously cooled and then drawn in the neighborhood of 150 degrees Cent. Fig. 6 illustrates this interesting point: That for the size of specimen used in this

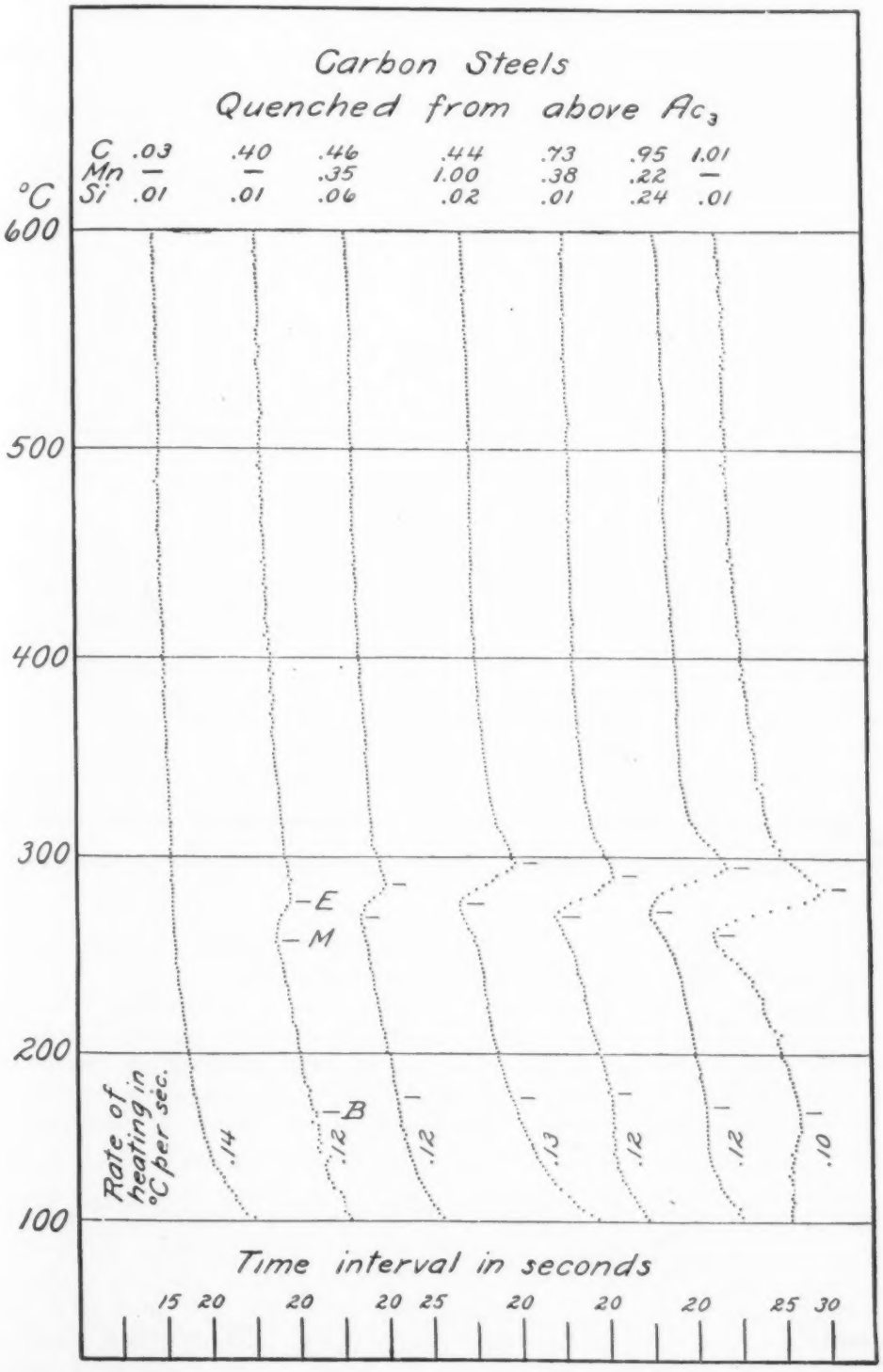

Fig. 4—Inverse rate heating curves of quenched steel, showing effect of composition

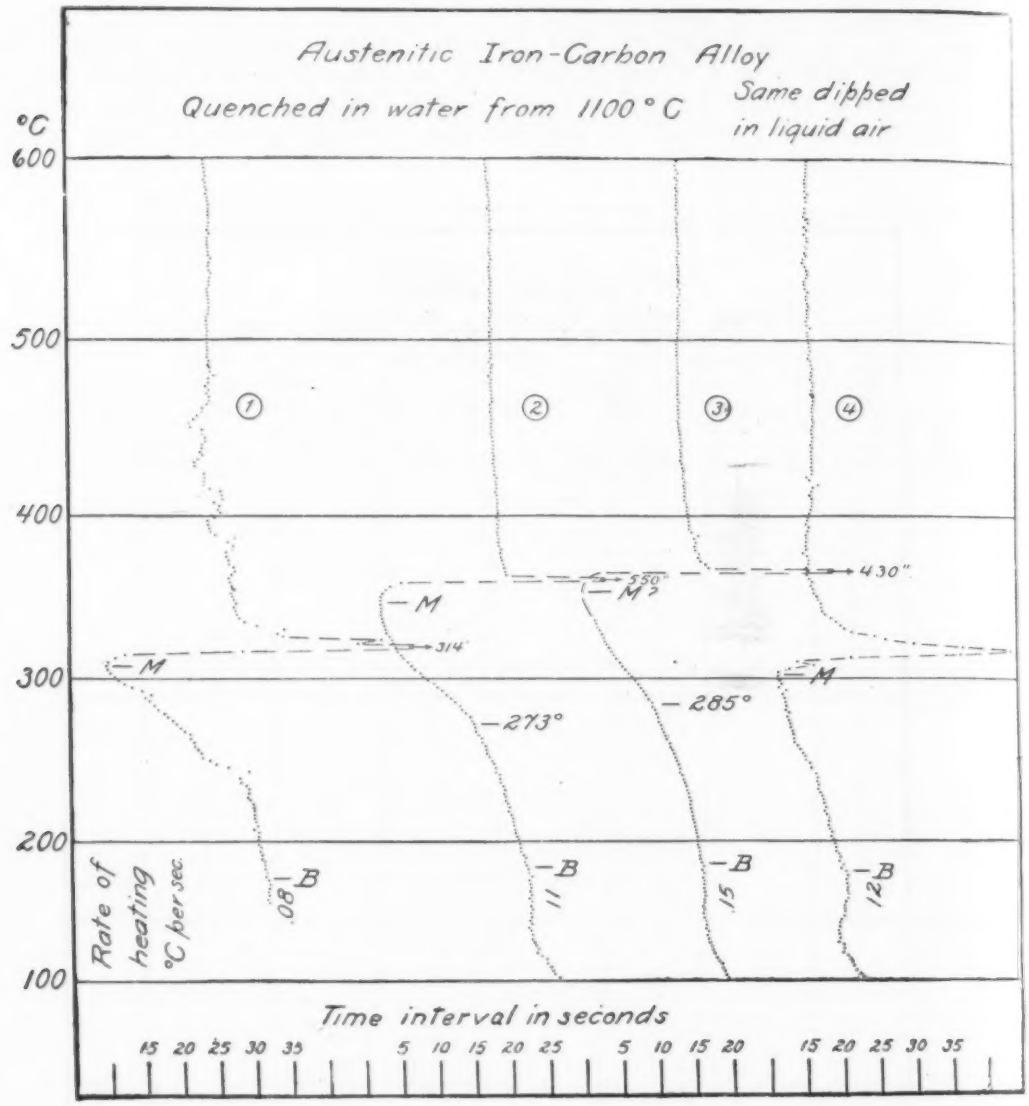

Fig. 5.—Inverse rate heating curves of austenitic iron-carbon alloy (1.94 per cent carbon)

case there is no appreciable difference between thermal characteristics of an oil-quenched and of a water-quenched specimen.

The heating curves represent the progress of tempering for a necessarily very short time at any temperature in the Ac_t range. To show the effect of holding for a definite time at several tempering temperatures on the characteristics of Ac_t, heating curves were taken on specimens of the 0.95 per cent carbon steel quenched in oil from 800 degrees Cent. and tempered 30 minutes at the temperatures given in Fig. 2 and Table II.

From a consideration of these data it may be seen: (1) That the beginning of Ac_t is from 10 to 17 degrees Cent. higher than the tempering temperature when that is above 200 degrees Cent.; (2) that the transformation is completed at a temperature between 250 and 270 degrees Cent; and (3) that for each temperature up to 250 degrees Cent. there is a definite and characteristic form of curve. The estimated temperature of the end of Ac_t for zero rate or 260 degrees Cent. is, therefore.

from (2) in practical agreement with the end of the transformation for a tempering period of 30 minutes. From (1) and (3) it is evident that the heating curves might be used to estimate the previous tempering temperature within certain limits.

It may be of interest to note that, for a tempering temperature of

Table II

THERMAL CHARACTERISTICS OF HARDENED CARBON STEELS

Composition			Heat treatment				Ac. temperature					
Carbon	Manganese	Silicon	Quenching temperature	Quenching medium	Tempering temperature	Time at tempering temperature	Rate of heating	Beginning	Maximum	End	Intensity of heat evolution	AC1 maximum
Per cent	Per cent	Per cent	Degrees Cent.		Degrees Cent.	Minutes	Degrees Cent. per sec.	Degrees Cent.	Degrees Cent.	Degrees Cent.	Seconds	Degrees Cent.
							(1) Effect of heating at different rates					
0.95	0.22	0.24	800	Water			0.23	183	290	319	5	735
			800	do			.16	178	285	308	7	.....
			800	do			.05	162	261	282	14	.....
			800	Oil			.22	167	273	295	8.5	733
			(a)				.23	.....	.....		0	736
							(2) Effect of tempering at different temperatures					
.95	.22	.24	800	Oil			0.12	167	273	295	8.5	733
			800	do	200	30	.13	215	275	300	9.0	733
			800	do	230	30	.13	240	282	307	1.5	733
			800	do	250	30	.15	267	.....	310	0.5	734
			800	do	270	30	.16	.....			0	734
			800	do	300	30	.15	.....			0	733
			800	do	350	30	.12	.....			0	733
			800	do	400	30	.17	.....			0	733
			(b)	do			.15	.....			0	735
							(3) Effect of tempering for different periods of time					
.95	.22	.24	800	Oil	200	5	0.15	204	276	300	9	.....
			800	do	200	30	.13	215	275	300	9	.....
			800	do	200	60	.16	224	273	300	4	.....
			800	do	230	5	.14	224	271	296	5.5	.....
			800	do	230	30	.13	240	282	307	1.5	.....
			800	do	230	60	.13	244	289	350	0.5	.....
							(4) Results for different compositions					
.40	.....	.01	900	Water			0.12	167	259	278	2	731
.46	.35	.06	900	do			.12	174	270	286	3	731
.44	1.00	.02	900	Oil			.13	174	276	297	6	727
.73	.38	.01	900	Water			.12	175	271	292	7	731
.95	.22	.24	800	Oil			.12	167	273	295	8.5	733
1.01	.....	.01	800	Water			.10	167	261	284	13	728
							(5) Results for austenitic structure					
											C. Temp. drop	
1.94	.....	0.01	1,100	Water			0.08	174	308	319	2	.....
			1,100	do			.11	182	347	361	24	.....
			1,100	do			.15	184	353	366	.....	731
			1,100	do	180	30	.12	179	302	317	0	.....

a Annealed. *b* Air cooled.

270 degrees Cent. and 300 degrees Cent., Fig. 2, there is a slight deflection of the curves to the right, indicating an absorption of heat over the range of about 350 to 450 degrees Cent., which is in conformity with the observations of Heyn and Bauer[10] under similar conditions.

It has long been recognized that the time of holding at a tempering

10 See footnote 3.

temperature has a very considerable effect on the resulting physical properties, and it is even held that a long time at a low temperature is equivalent to a short time at a higher temperature. The thermal curves of steels tempered for different lengths of time in the Ac_t range should, therefore, throw some light on the validity of this much discussed proposition.

In Fig. 3 heating curves are given to show the effect of maintaining a steel for different lengths of time at the tempering temperature. The

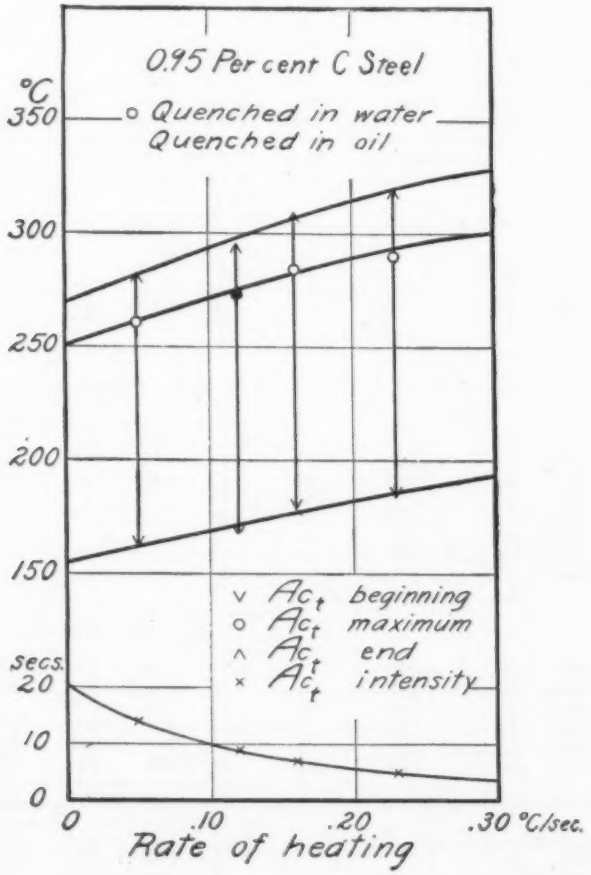

Fig. 6—Effect of rate of heating on temperature and intensity of heat evolution of 0.95 per cent carbon steel

0.95 per cent carbon steel, hardened by being quenched in oil from 800 degrees Cent., was used. Specimens were maintained for 5, 30 and 60 minutes at each of the two tempering temperatures, 200 and 230 degrees Cent., chosen because they represent temperatures at which tempering is well in progress, but not to such an extent as to eliminate the thermal effect.

It may be noted from these curves and the compiled data of Table II: (1) That the beginning of Ac_t is higher for a long than for a short exposure at the tempering temperature; (2) that the intensity of the transformation is less for a long tempering period than for a shorter one; and (3) that the rate of progress of the transformation is greater at the higher tempering temperature than at the lower one.

From (1) and (2) it is apparent that time has a decided effect on

the transformation characteristics. The third conclusion is evident from the fact that at 200 degrees Cent. an exposure of 60 minutes is necessary to reduce markedly the intensity of Ac_t, while at a temperature only 30 degrees Cent. higher the intensity is much more strongly reduced by a 30-minute exposure. This is in agreement with the tempering experi-

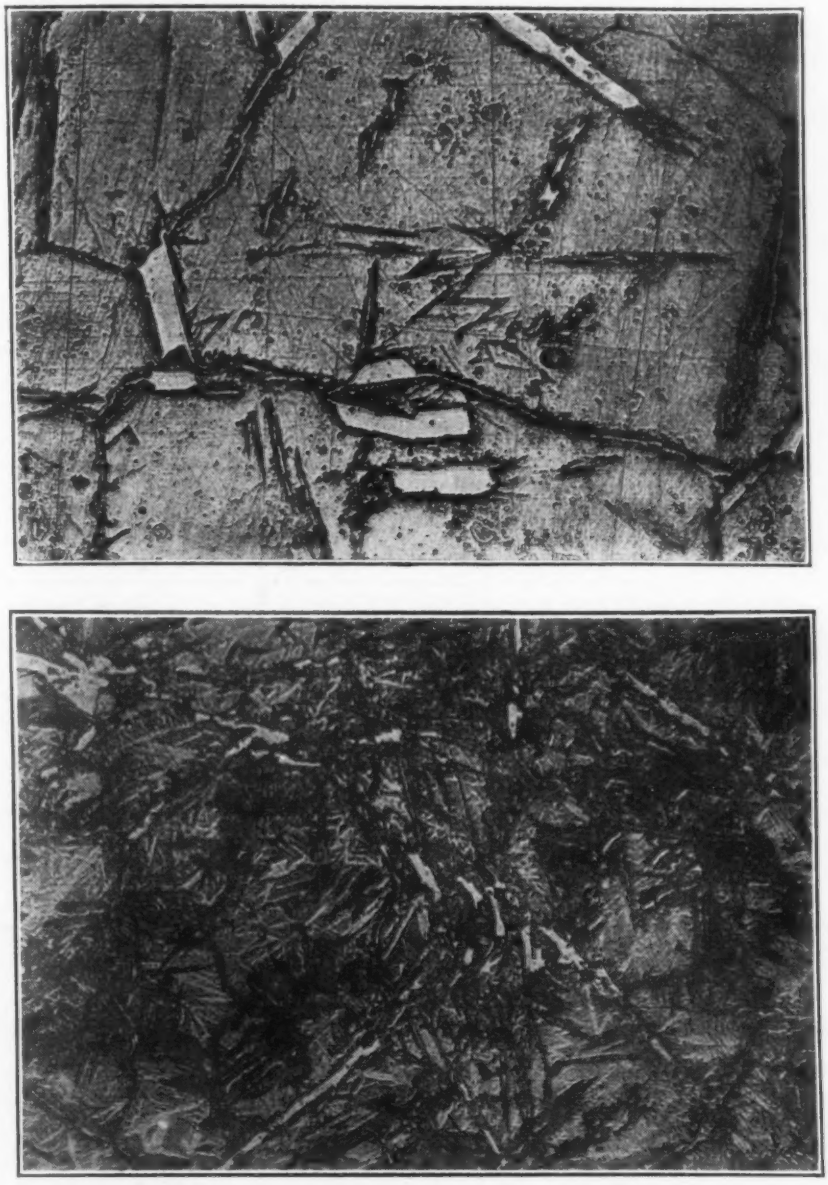

Fig. 7—Microstructure of 1.94 per cent carbon steel quenched in water from 1100 degrees Cent. Etched with 2 per cent alcoholic nitric acid. (Above) As quenched. x 500. (Below) Same as above but dipped in liquid air 30 minutes. x 500

ments of Barus and Strouhal,[11] whose measurements of electrical resistance and thermal emf show the rate of transformation to be much greater at the higher tempering temperatures in the Ac_t range. This indicates further that the tempering time of 30 minutes used in the preceding section represents actual equilibrium or zero-rate conditions at the tem-

11 Barus and Strouhal, Bull. U. S. Geological Survey, No. 14; 1885.

perature of the end of Ac_t, though, of course, not at lower temperatures.

It may be inferred from the nearly identical characteristics of Ac_t following tempering for 60 minutes at 200 degrees Cent. and 5 minutes at a temperature 30 degrees Cent. higher, that these two treatments produce the same structural condition, but, because the rate of transformation changes with temperature, it does not follow that this particular relation holds quantitatively for any other temperatures in the Ac_t range.

In general, however, the effect of time may be regarded as equiva-

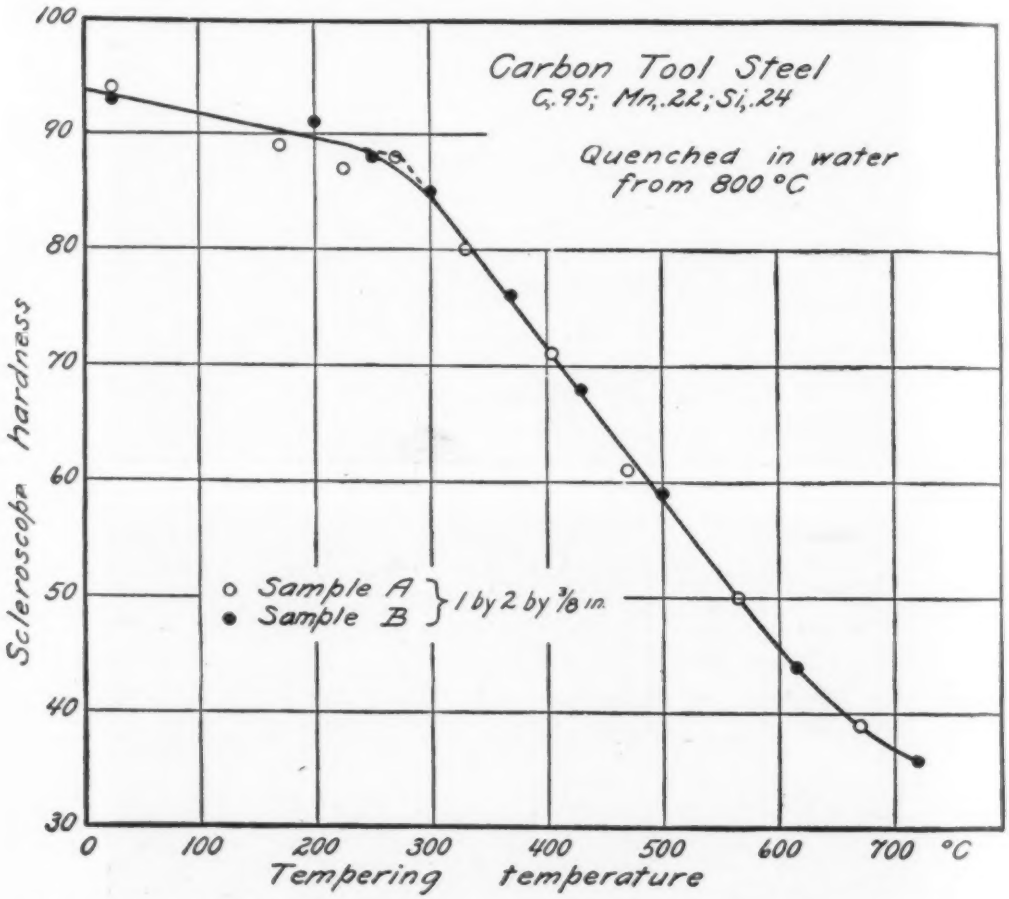

Fig. 8—Effect of tempering temperatures on scleroscope hardness of 0.95 per cent carbon steel

lent to that of temperature within limits as far as the characteristics of Ac_t are a criterion of the constitutional changes in the steel.

For the sake of comparison of the several martensitic steels investigated, the temperature values of Ac_t taken from Table II have been given a small correction on the basis of Fig. 6 to reduce them to a constant rate of heating of 0.10 degrees Cent. per second; these values are given in Table III. By comparing the synthetic steels in the first group, low in manganese, or the commercial steels in the second group, containing 0.20 to 0.40 per cent manganese, with respect to the variable carbon, one may see that the maximum and end of Ac_t are somewhat higher for the higher carbon contents and that the transformation intensity is approximately proportional to the carbon content.

The effect of an increase of carbon on the heat evolution is to augment correspondingly the rate at a given stage in the progress of the

transformation for a given furnace rate. This increase in rate from the effect noted on rate of heating, will raise the temperature of the maximum and end of Ac_t. The increase in temperature of the maximum and end of Ac_t with increasing carbon, being small, is probably due entirely to the augmented rate of heating. This factor being ineffective for very slow or zero rate of heating, it may be stated that, for this case, the carbon does not materially affect the maximum and end of Ac_t. Likewise, the rate at the beginning is unaffected by the subsequent heat evolution, so that the constancy of that point verifies the conclusion that the temperature of Ac_t is practically independent of carbon content under conditions which render the effect of intensity impotent.

From Table III it may be of interest to note further that Ac_t is slightly higher in the commercial than in the pure synthetic steels of the same carbon content, and that the characteristics of Ac_t for the steel

Table III

TRANSFORMATION CHARACTERISTICS OF MARTENSITIC STEELS FOR RATE OF HEATING OF 0.10 DEGREES CENT. PER SECOND

Carbon	Manganese	Silicon	Ac. temperature			Intensity
			Beginning	Maximum	End	
Per cent	Per cent	Per cent	Degrees Cent.	Degrees Cent.	Degrees Cent.	Seconds
Synthetic Steels						
0.40	.....	0.01	165	255	274	2
1.01	.....	.01	167	261	284	13
a1.94	.....	.01	177	298	313	32
Commercial Steels						
.46	.35	.06	172	266	282	3
.73	.38	.01	173	267	288	7
.95	.22	.24	165	269	291	8.5
Synthetic 1 Per Cent Mn Steel						
.44	1.00	.02	170	270	291	6

a Martensitic by immersion in liquid air; curve 4, Fig. 5.

containing 0.73 per cent carbon and 0.38 per cent manganese are practically identical with those for the steel containing 0.44 per cent carbon and 1.0 per cent manganese.

For obtaining the data presented in preceding examples, the material used was a martensitic steel, but it was believed to be of some interest to study also the thermal changes accompanying the decomposition of an austenitic matrix in a carbon steel. With this in mind, a steel of 1.94 per cent carbon content was quenched in water, the resulting structure being uniformly austenitic as shown in Fig. 7*a*.

The curves taken on specimens given such treatment are shown in Fig. 5, curves 1, 2, and 3, and the data taken from them, are shown in Table II. The transformation observed was very intense, and in one case, Fig. 5, curve 3, the heating advanced so rapidly that the operator could not follow it. In every case the heat evolution increased the specimen temperature at the end of the transformation so that it exceeded the normal furnace temperature, and a drop of temperature was then recorded. This amounted to 2 degrees Cent. in curve 1 and 24 degrees Cent. in curve 2; the drop for curve 3, though not recorded, was very considerable.

In these austenitic steels the effect of rate of heating upon the temperature of Ac_t is much more pronounced than in the martensitic steels, though with slow rates the difference between the two types of steel is small, if any. Thus by comparison of curve 1 for the austenitic steel

(rate of heating, 0.08 degree Cent. per second) with the curve for the 0.95 per cent carbon steel (rate of heating, 0.16 degree Cent. per second), in both of which cases the rate is approximately the same at the maximum, one may note that the maximum for the austenitic steel is 23 degrees Cent. higher and the end only 11 degrees Cent. higher than for the martensitic steel, even though an actual temperature drop occurred in the former case. This would indicate that for very slow rates there would be little temperature difference between Ac_t for a martensitic

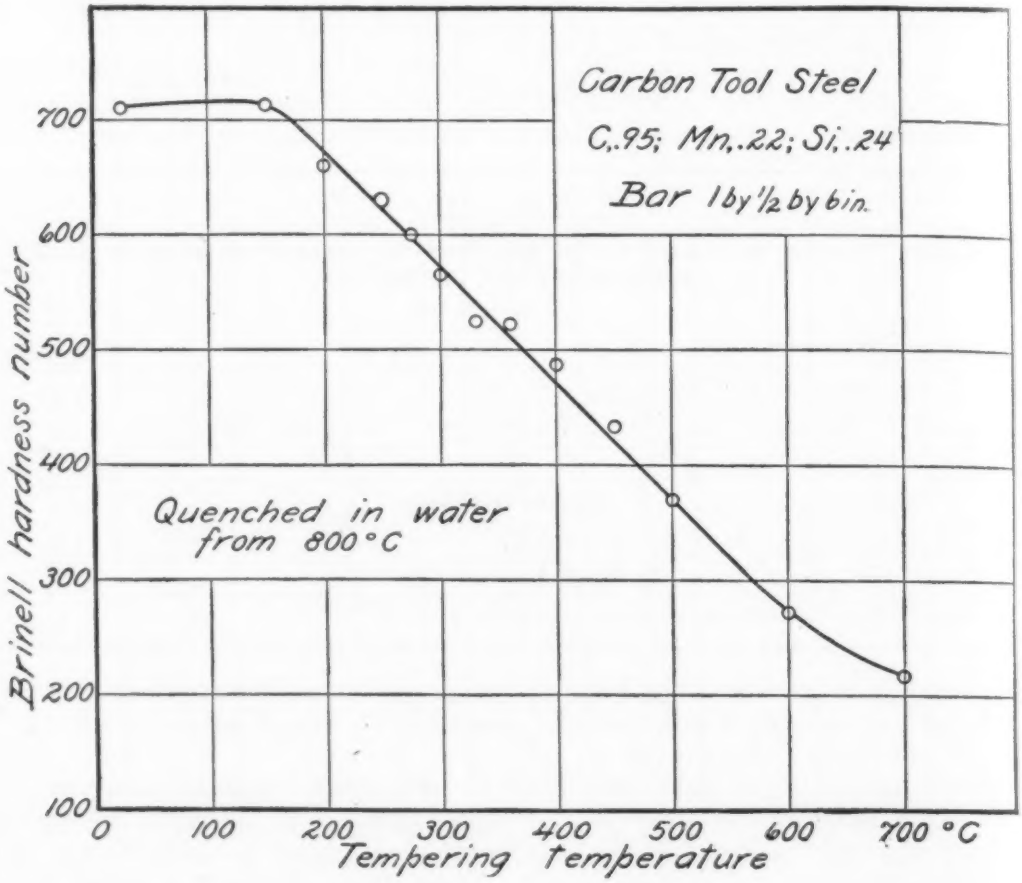

Fig. 9—Effect of tempering temperature on Brinell hardness of 0.95 per cent carbon steel

structure and Ac_t for an austenitic one. Here again the fact that the beginning for both is practically the same verifies the conclusion that the heat evolution of the transformation materially affects its observed temperature for sensible rates of heating.

Curve 4 of Fig. 5 shows the thermal characteristics of one of the austenitic steels after exposure for 30 minutes in liquid air. This treatment rendered the steel partially martensitic in structure as shown in Fig. 7*b*. Comparison of the heating curve 4 for this sample with curve 2, the rate of heating being essentially the same in both cases, shows that treatment in liquid air causes (1) a lowering of the maximum and end of the transformation by about 45 degrees Cent., and (2) an evolution of heat much less intense, without any recorded drop of temperature. This indicates a marked structural change, evidently from austenite to martensite, on immersion of the austenitic steel in liquid air.

Further examination of the heating curves of the austenitic steels reveals another significant phenomenon. An inflection in these curves may be noted at 273 degrees Cent. for curve 2, 285 degrees Cent. for curve 3, and somewhat lower for curve 1, at which temperature there is an augmentation of the rate of heating. It is evident from curves 2 and 4 that the heat evolution of the latter or martensitic steel starts to drop

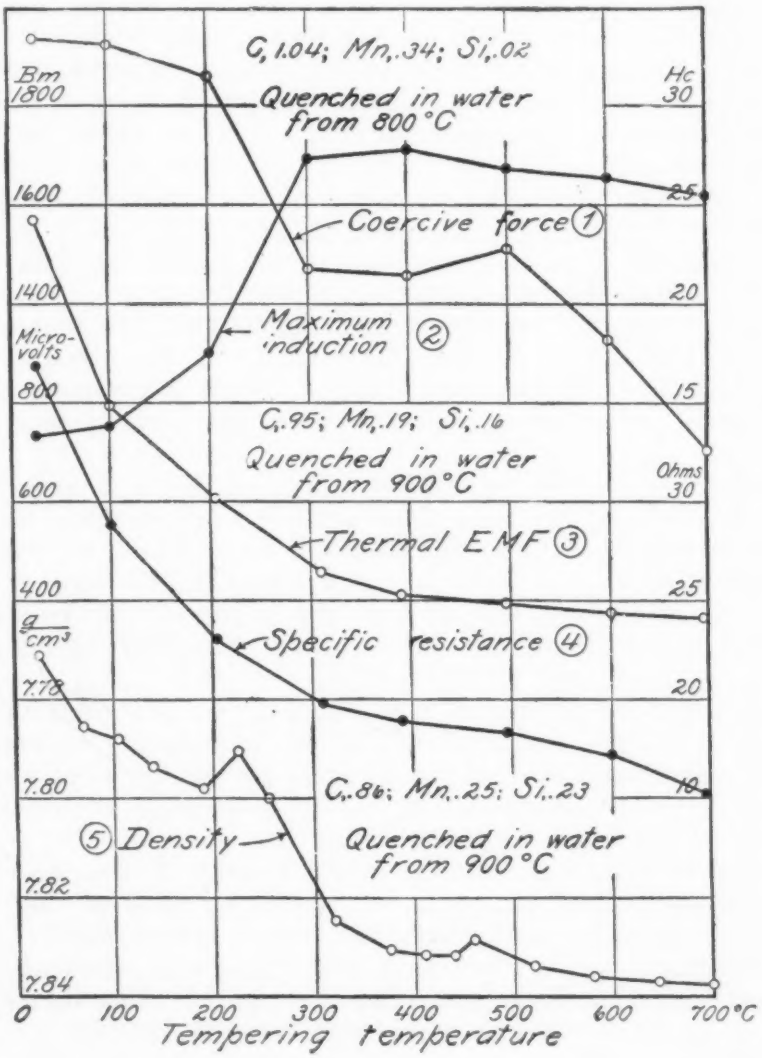

Fig. 10—Change of physical properties with tempering temperature of martensitic carbon steels

off, while the former or austenitic steel is considerably intensified just above the inflection temperature of 273 degrees Cent. This indicates two stages in the decomposition of the austenitic steel—namely, the low temperature stage, probably a manifestation of the simple carbide precipitation, and the high temperature stage, which is the same intensified by the A_3 and A_2 transformation. In the case of the martensitic steel the change designated by Ac_t is very probably due only to the carbide precipitation.

The thermal curves presented here show a rapidly increasing heat evolution (Ac_t) from 155 to 250 degrees Cent., ending abruptly at about

260 degrees Cent. for a very slow heating rate. This last temperature, 260 degrees Cent., very probably represents the completion of the change from martensite into troostite. A consideration of the changes in physical properties on tempering quenched steels through the Ac_t range should, therefore, assist materially in determining other characteristics of this change.

In order to make a reliable comparison of the characteristics of Ac_t with the changes in the standard scleroscope and Brinell hardness numbers, measurements were made on samples of the 0.95 per cent carbon steel used for the majority of the thermal curves. The results are shown in Figs. 8 and 9, the recording scleroscope being used in the first case and the usual Brinell equipment in the latter. A fresh surface of the ball was taken for every impression.[12]

For the purpose of comparing some of the other physical properties with the heat evolution, Fig. 10 was prepared. Curves 1 and 2 of this figure were obtained from the magnetic data of Burrows and Fahy[13] and are expressed in gausses per square centimenter; curves 3 and 4 were obtained from the electric resistance and thermal electromotive force data of Campbell,[14] and curve 5 was obtained from the density values of Schulz.[15] In all cases martensitic carbon steels were used of approximately the same carbon content as the 0.95 per cent carbon steel used here.

Upon returning to the hardness curves of Figs. 8 and 9 one may see that the scleroscope hardness does not drop off abruptly until slightly above the temperature 260 degrees Cent. of the end of Ac_t, and that the Brinell hardness begins to drop linearly immediately above the beginning of Ac_t. Thus there exists in both the hardness curves an inflection closely related to fundamental temperature characteristics of the heat evolution.

Consideration next of curves 1 and 2, Fig. 10, for coercive force and maximum induction, respectively, will show that these properties change with an increasing rate over the range 20 to 300 degrees Cent. in the same manner as the heat evolution. The tempering temperature steps were not taken sufficiently close to define the end point of this change, but it coincides substantially with the end of Ac_t. The curves 3 and 4, for thermal electromotive force against pure iron and specific resistance, respectively, are practically parallel and may, therefore, be considered as a unit. It may be observed that the change is about 85 per cent complete at 300 degrees Cent., or in the Ac_t range. The density curve 5 is somewhat irregular, but the maximum rate of change occurs in the vicinity of the end of Ac_t.

From the foregoing analysis it is evident that the changes in the physical properties considered are related very closely to the heat evolution Ac_t, particularly in the case of the magnetic properties, maximum induction, and coercive force. These relations are forceful indications of a natural boundary between martensite and the troostite produced at about 260 degrees Cent. on tempering. Such a boundary should be detectable also by the changes in microstructure. Authorities, however, differ on the temperature of this boundary for simple steels, and place

[12] Since these Brinell data were obtained, the work of Chevenard (see footnote 5) appeared, containing a curve for an 0.85 per cent C steel practically identical in form with Fig. 9, with the exception that his values are somewhat lower.

[13] Burrows and Fahy, Trans. A. S. T. M., 19, part II, p. 5; 1919.

[14] Campbell, J. Iron and Steel Inst., 94, p. 268; 1916.

[15] Schulz, Forschungsarbeiten, No. 161, p. 1; 1914.

it anywhere in the range from 250 degrees Cent. to 400 degrees Cent. Careful observers have studied this change, and while not suggesting an end point, have made observations indicative of one in the region of the end of Ac_1.

Howe and Levy,[16] after quenching eutectoid carbon steel from 1100 degrees Cent. to water, find that on a 5-minute exposure to 300 degrees Cent. the original white martensite needles are almost completely broken up. Heyn[17] notes a coarsening of the needle structure at 275 degrees Cent. These observations are indicative of a structural change in the vicinity of the end of the heat evolution. The region under investigation is thus narrowed down, and future observers should have little difficulty in defining precisely the nature of the accompanying changes.

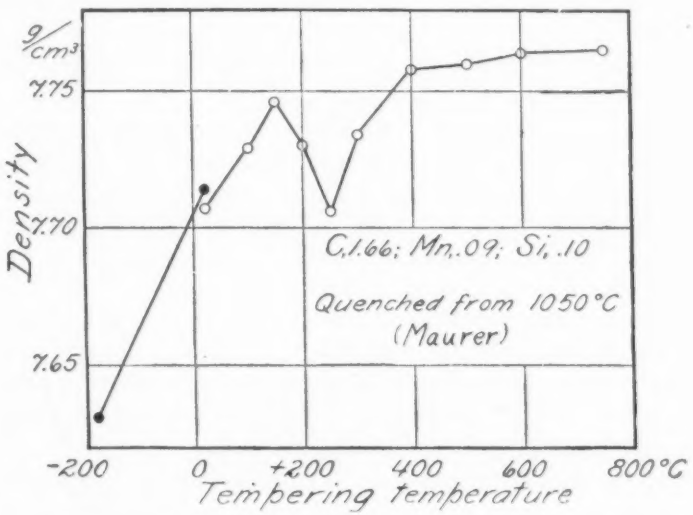

Fig. 11—Change in density with tempering temperature of semi-austenitic carbon steel (Maurer)

In foregoing paragraphs attention was called to a sharp change in direction of the heating curves of the austenitic steel. This inflection, denoting an abrupt increase in the rate of heat evolution, was noted to start at about the temperature at which the heat evolution in a martensitic steel begins to disappear. It may therefore be of some interest to compare this thermal behavior of the steel with the density changes in similar steel. In Fig. 11 are plotted density values given by Maurer[18] for a 1.66 per cent carbon steel quenched in water from 1.050 degrees Cent. The resulting structure is not completely austenitic, but nearly so. The curve shows three distinct regions: (1) 20 to 150 degrees Cent., in which the density increases as in a martensitic steel; (2) 150 to 250 degrees Cent., in which a drop occurs which recalls the second stage of the heat change of the austenitic steel; and (3) above 250 degrees Cent., in which it follows the normal course of a martensitic steel. Since martensitization implies a decrease in density (see the black circles of Fig. 11, representing the density change on immersion in liquid air), the second step with a density drop is evidently attributable to completion of the change from austenite to martensite, which is more or less transformed into

[16] Howe and Levy, Trans. A. S. T. M., 16, part II, p. 7; 1916.
[17] Heyn quoted by Sauveur, The Metallography and Heat Treatment of Steel, p. 304.
[18] See footnote 2.

troostite. The augmentation of the heat evolution of the austenitic steels, as previously explained, is therefore definitely verified.

In this paper the transformation, observed as an evolution of heat, on heating curves of hardened steel has been designated here as Ac_t, and its characteristics as revealed in carbon steels have been investigated. The effect of several variables was noted with the following conclusions:

1. An increase in the rate of heating raises markedly the temperature of Ac_t for a 0.95 per cent carbon martensitic steel and has a yet more marked effect for an austenitic carbon steel. For zero rate of heating there appears, however, to be little, if any, difference between the principal temperatures, whether the steel is of high or low carbon content or whether it is martensitic or austenitic. The principal temperatures for the 0.95 per cent carbon martensitic steel were found to be 155, 250, and 260 degrees Cent., respectively, for the beginning, maximum, and end.

2. The results obtained for specimens tempered at different temperatures before taking heating curves confirm substantially the temperature of the end of Ac_t just given.

3. Tempering for a short time at a temperature within the Ac_t range has an effect on the transformation characteristics similar to tempering for a longer time at a somewhat lower temperature.

4. The heat evolution of the austenitic steel takes place in two steps, the second being probably connected with the transition from austenite to martensite.

5. A survey of the changes in some physical properties of martensitic carbon steels through the tempering range leads to the conclusion that these changes are all directly related to the heat evolution observed, but only in the case of the magnetic properties, coercive force, and maximum induction is the change of the same type.

6. The change in density of a semiaustenitic carbon steel proceeds in steps similar to the heat evolution of the austenitic steel.

7. The changes in microstructure on tempering martensitic steels are unquestionably related to the heat evolution, but further study is necessary to establish fully this relation. The end point, 260 degrees Cent. for zero rate of Ac_t may very properly be taken as the natural boundary between martensite and the troostite of tempering, representing as it does the end of the transformation suppressed on rapid cooling.

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News of the Chapters

A BIG year is planned by the Pittsburgh Chapter. On August 23, the council of the chapter met at a dinner at the Hotel Chatham for the purpose of discussing plans for the coming year. This council was made up of about 20, including the various officers and members of committees. Doctor Johnson, recently elected chairman of the chapter is ambitious to make it the biggest year the Pittsburgh chapter has ever known and accordingly has been holding various committee meetings to complete arrangements. It was decided that the entertainment committee should provide some special entertainment feature for each regular meeting. This feature will be in the nature of a surprise.

An unusually prominent and interesting group of speakers has been secured for the coming meetings, which will be held on the first Tuesday of each month. At the first meeting, Sept. 6, Professor MacIntosh of Carnegie Institute of Technology will speak on "The Metallurgy of Iron and Steel." This meeting will be in the Hotel Chatham and will be preceded by a dinner at 6:30 and the special entertainment feature mentioned above. The October meeting will be addressed by Charles E. Carpenter.

president of the E. F. Houghton Co. a speaker who is nationally known. His subject will be "Individualism vs Socialism. In November, Prof. Albert Sauveur of Harvard University, will speak on the "Heat Treatment of Steel." In December Prof. H. F. Moore of the University of Illinois will discuss "Fatigue Testing and Resistance of Materials." Col. A. E. White of the University of Michigan will discuss "Alloy Steel" at the January meeting. Other speakers of prominence who will address the chapter at later dates are: Prof. F. M. Crabtree of the Carnegie Institute of Technology; Prof. S. L. Goodale of the University of Pittsburgh; Dr. J. S. Unger of the Carnegie Steel Co. and Frank P. Gilligan of the Southern Engineering Co. and president elect of the National Society.

At the meeting delegates were appointed to the National Convention in Indianapolis, September 19 to 24 and instructed to bring the 1922 convention to Pittsburgh.

Commercial Items of Interest

AN INTENSIVE night course in metallography for heat treaters, chemists and laboratory assistants is to be conducted by the Cleveland School of Technology sponsored by the Central Young Men's Christian Association. C. G. Shontz, metallurgist of the Perfection Spring Co., Cleveland and secretary of the Cleveland Chapter of the American Society for Steel Treating will be the instructor. Classes will be held two and one-half hours on two evenings of each week for a period of 16 weeks. The outline of the course includes: Physical tests and their value; iron and steel; pure iron; wrought iron and low carbon steel; medium and high carbon steel; impurities in steel; mechanical treatment of steel; pyrometers and thermal critical points; iron—carbon diagram; cast steel; annealing of steel; hardening and tempering; cementation and case hardening; alloy steels; cast iron and malleable iron; and defects and failures.

The Case Hardening of Steel by Harry Brearley is the title of a 208-page book published recently by Longmans, Green & Co., New York. By way of review *The Iron Trade Review* says:

"Changes in structure and properties induced in steel by cementation and allied processes is the subject treated by this book which is made complete by the use of many illustrations. Since the material was developed mainly for the use of those actively engaged or interested in the commercial manufacture of case hardened products, the chapters are arranged to appeal to the workshop experience of the workmen.

"In preparation of the book, effort has been made to explain the microphotographs in as simple terms as possible. The author points out that an explanation based on the mechanical structure of an object is intelligible, because most minds can appreciate the elements of design and pass judgment on the composite properties of the materials. For that reason numerous microphotographs are used, and for the same reason, the writer states, the assistance offered by microscopic methods,

whatever the means of magnification are available, should not be ignored in workshop practice.

"The first edition of the book was published in 1914 but has been out of print for some time. As a result of the war and advances in heat treatment made by the urgent demands for steel, many changes have occurred. In preparing the second edition, therefore, the author has included the most recent revisions in metallurgical practice."

H. B. Knowlton, consulting metallurgist of the Case Hardening Service Co., Cleveland, manufacturers of case hardening material is taking a post graduate course in the department of metallurgy at Columbia university.

To show his appreciation of the honor conferred upon him by the presentation of the John Fritz Medal, Sir Robert A. Hadfield of London, Eng., has published an elaborate 42-page booklet containing his address of thanks made before the Institution of Civil Engineers. The booklet shows the photographs of previous recipients of the medal together with a history of the awards. Sir Robert briefly outlines his discovery of and research with manganese steel in which connection the medal was awarded.

A new line of electric furnaces, added to the products of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., is described and illustrated in a 24-page illustrated booklet recently published by that company. The new type of furnace includes the multiple unit designed for use with heats of 1800 to 2000 degrees Fahr. According to the booklet the small heavy-duty furnaces of the multiple crucible type may be operated continuously at 2000 degrees Fahr. In the booklet heavy-duty industrial furnaces with appliances for annealing, hardening, drawing and enameling are described in detail and in addition a discussion of the characteristics of these furnaces is given.

The agency arrangement for the sale of sheet steel heretofore existing between Thos. Firth & Sons, Ltd., of Sheffield, and Wheelock Lovejoy & Co. of New York and Cambridge, has been terminated, and Thos. Firth & Sons have appointed as their general sales manager for the United States Horace G. Hides of Hartford, Conn., who has for the past 20 years represented Wm. Jessop & Sons. The stock of Firth Sheffield sheets will be carried in the warehouse of an associate company the Firth-Sterling Steel Co., 312 Hudson street, New York. Thos. Firth & Sons and the Firth-Sterling Steel Co. are also opening a joint office in Hartford, Conn., where Mr. Hides will have his headquarters and where Henry I. Moore will represent the Firth-Sterling Steel Co.

Historical sketches of the discovery and the subsequent development of vanadium steel together with a description of the uses of steel containing this alloy are given in a booklet recently issued by the Vanadium Corp. of America, New York. According to the text, 90 per cent of the vanadium produced comes from deposits at Cero de Pasco, Peru.

The major portion of the booklet is devoted to a description of the products which are manufactured from vanadium-alloy steel. Some of these commodities are airplane fittings and engine parts, cast iron shell forging tools, torpedo air flasks, armor plate, steel helmets, submarine

crankshafts, caterpillar mounts for naval guns, valve gears, locomotive parts, large castings for cores and shafts, roller bearings, automobiles and tucks, springs, tool steel, piston rods, and air compressors. Charts in the last pages of the publication show the physical properties at different drawback temperatures. The booklet contains 50 pages and is illustrated throughout.

The General Alloys Co., New York, announces that it has developed a new heat resisting alloy which will be marketed at an unusually low base price. This alloy, it is said, has about four times the life of steel and has the additional advantage of retaining its shape at high temperature. It is covered by a basic principle recently issued. The new metal is a development of 11 years research and experiment. Over 30 tons of experimental castings were made and tested before the material was placed on the market.

Anthracite coal and its production will be the principal subject for discussion at the semicentennial anniversary meeting of the American Institute of Mining and Metallurgical Engineers to be held at Wilkes-Barre, Pa., Sept. 12-15. At the metal section, which will convene Monday night, the following papers will be presented: "Application in Rolling of Effects of Carbon, Phosphorus and Manganese on Mechanical Properties of Steel" by W. R. Webster; "Thacher Process for Molding and Casting Propeller Blades and Wheels" by E. Touceda; and "Making a 5 Per Cent Nickel-Cast Iron Alloy in an Electric Furnace," by D. N. Whitman.

The George J. Hagan Co., Pittsburgh, Pa., has just completed the erection of a modern steel factory building adjacent to its foundry at Orrville, O. This building is to be used for construction and development work on all types of furnaces and furnace equipment .

E. S. Crosby, sales and advertising manager for the United States and Cuban Allied Works Engineering Corp., has resigned to become manager of the eastern district of the Celite Products Co., producers of an insulating material and a filtering medium. Previous to his service in France with the army, he was assistant sales manager for the De-Laval Steam Turbine Co., Trenton, N. J. Mr. Crosby will make his headquarters at 11 Broadway, New York.

Ralph C. Schwarz has taken over the northwestern New York territory for the distribution and sale of industrial furnaces and appliances manufactued by the Chicago Flexible Shaft Co., Chicago. Mr. Schwarz's address will be 921 Granite building, Rochester, N. Y.

"Furnaces for the Heat Treatment of Metals" is the title of an 8-page catalog issued recently by the Barkling Fuel Engineering Co., 1743 N. Kenton avenue, Chicago. Four of the furnaces described are an oven furnace for hardening high speed and carbon steels; an oven furnace for heat treating, carbonizing and annealing; a forging furnace for drop hammer; and bull dozer work; an annealing, tool and die

(*Concluded on Page* 36)

CASEITE

The Standard Case Hardener

The case hardening of steel without the danger of deadly fumes appeals to the human side of steel treating. That accurate results are obtained and duplicated at all times by using CASEITE appeals to the hardening room Foreman. Increased production, low first cost and a better product are the reasons so many managers insist on CASEITE.

SPECIFY CASEITE

Visit our exhibit at the American Society Treating Convention Booth No. 74, Indianapolis, Sept. 19 to 24.

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St. Louis, Mo.	E. H. Sachleben & Co., 1517 Olive St.
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HAGAN CO.

BUSTION ENGINEERS

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a Complete Line of

TREATING FURNACES

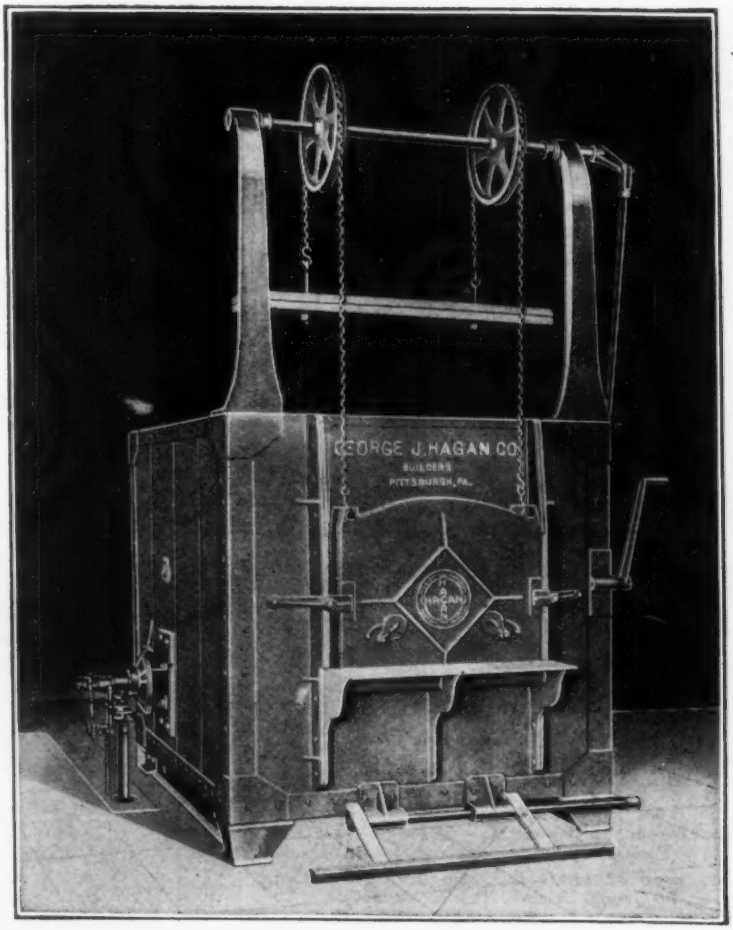
COMBUSTION TYPE

Both types of furnaces may be seen in operation at booths 8 and 9, Heat Treaters Convention, Indianapolis, Ind., September 19th to 24th. Full construction details and valuable data will be found in bulletins mentioned.

For circular on Combustion Furnaces ask for

Bulletin LF-105

Hagan Standardized Combustion Heat Treating Furnace Liquid or Gaseous Fuel

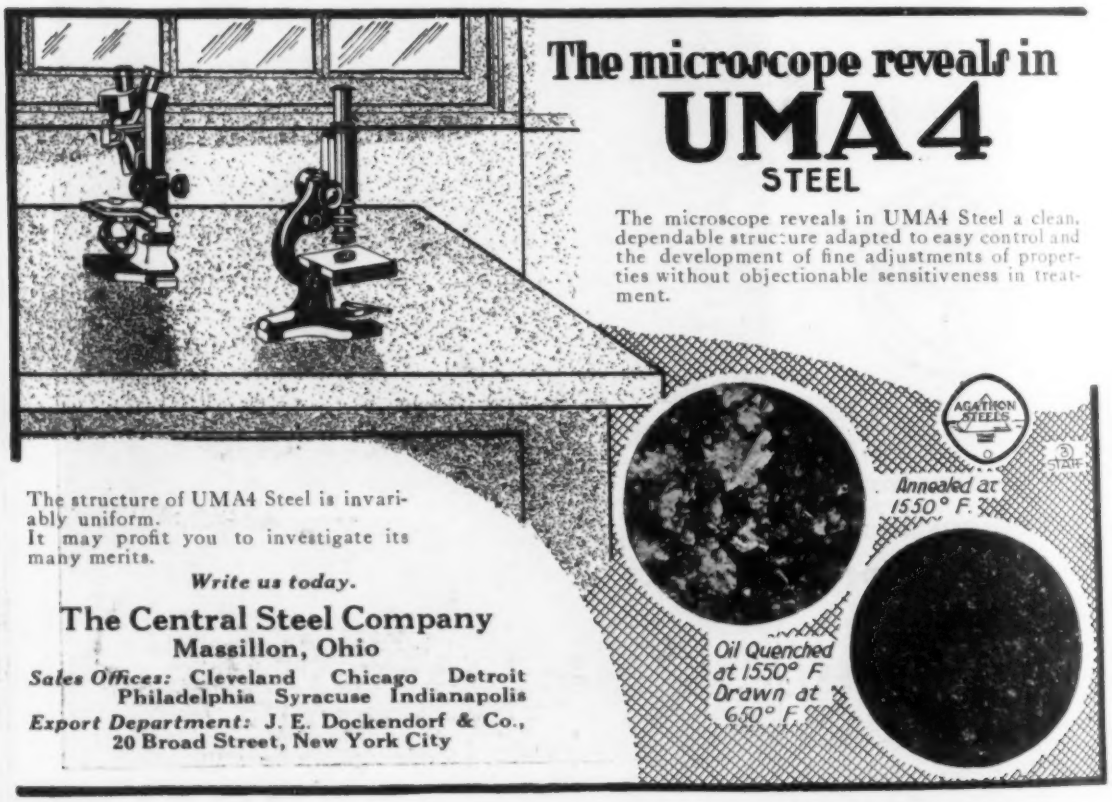


(*Concluded from Page 779*)

heating oven type furnace for reheating and carbonizing; and a crucible furnace for lead and cyanide hardening. Each type is shown by illustration.

A catalog distributed by the Steel Treating Equipment Co., metallurgical engineers, Detroit, discusses two case hardening compounds manufactured by that company. The first carburizing compound is made in two sizes, one slightly larger than corn and the other about the same as rice, and is light in weight, free from dust and nonpoisonous. The second compound is manufactured in plastic form and is used where it is necessary to localize or confine the penetration to a given part of the subject under treatment. It must be applied to the surface to be hardened under pressure ranging from 350 to 390 pounds per square inch. It is especially suited to the hardening of ring gears and for this work a machine has been developed to press the compound about the gears. The gear is placed on the platen and the compound is spread on the teeth. After the die is placed on top, a foot treadle is operated which causes packing of the compound.

According to a recent announcement, the Brown Instrument Co., Philadelphia, has developed a new thermoelectric pyrometer which is automatically compensated in the instrument for changes in cold junction temperatures. A new feature of the equipment includes a means for setting the pointer to zero in the usual manner.


The microscope reveals in
UMA4
STEEL
The microscope reveals in UMA4 Steel a clean, dependable structure adapted to easy control and the development of fine adjustments of properties without objectionable sensitiveness in treatment.
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Annealed at 1550° F.
Oil Quenched at 1550° F. Drawn at 650° F.
The structure of UMA4 Steel is invariably uniform.
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Free the heat treatment from any blame for poor tool performance

Locate and remedy the real cause of the trouble.

THE KEYSTONE WATCH CASE CO.
ESTABLISHED 1853
RIVERSIDE WORKS
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Leeds & Northrup Co.,

Philadelphia, Pa.

ATTENTION MR. TALL.

Dear Sir:-

We have used, for the past eight or nine months, one of your Electric Hardening Furnaces and an Electric Drawing Furnace, together with your Potentiometer System with Curve Drawing Recorder. The results obtained have been very satisfactory and while we have experimented to secure maximum results with only a very few classes of our tools, we have obtained some very surprising results as to increase tool performance.

I think probably we have experimented to date with pieces of very much smaller mass than you have dealt with elsewhere but we find equally uniform results on small pieces treated in mass as on larger pieces separately treated.

It is the Writer's personal opinion, however, that you have overlooked one of the best talking points in favor of your Apparatus. In practice, when tools or parts continually broke in service or gave very varied results in the way of performance, the variation in hardening was always blamed. It has been our experience, however, that by this system we were practically applying to the hardening, the Micrometer that the Tool Makers used in making tools and we still obtained the varied tool performance. This led us to believe that we were either using wrong material or that the design was faulty and after changing one or the other, a surprising increase in life and performance of tool or die could be obtained. This may be a rather novel deduction but it was certainly true in our case and I believe exists in many shops.

We very much appreciate the service your Company has always given us and assure you of our readiness to co-operate at any time.

Yours very truly,

BHJ:MB

B H Johnson, Engr.

Complete equipments for hardening by the Hump Method, and various types of Potentiometer Pyrometers will be in operation in our booth at the Exposition.

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Electrical Measuring Instruments
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Perhaps you're still skeptical? All right! Write a letter asking for it and we will send you without obligation a sample big enough to prove it. Tear this advertisement out and put in your "To Dictate" folder—now.

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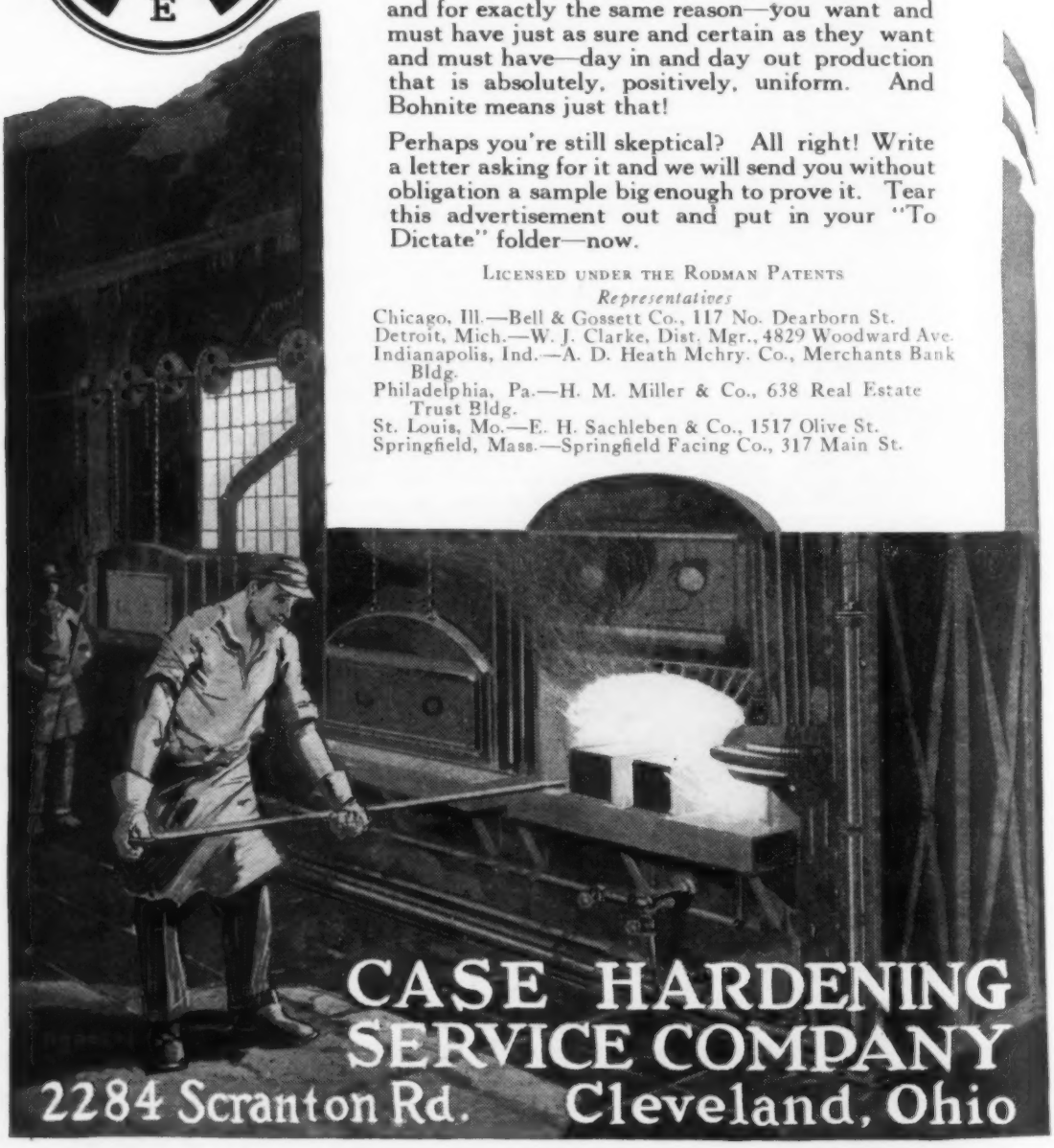
Philadelphia, Pa.—H. M. Miller & Co., 638 Real Estate Trust Bldg.
St. Louis, Mo.—E. H. Sachleben & Co., 1517 Olive St.
Springfield, Mass.—Springfield Facing Co., 317 Main St.



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AN INSTRUMENT FOR EVERY APPLICATION, designed and manufactured by SPECIALISTS. Let us recommend the correct instrument for your particular application.

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For Case Hardening

Cyanide Chloride Mixture $^{73}/_{76}\%$

is recommended as giving quick and accurate results.

The ideal material for a thin case and for reheating of high carbon steel is

R & H Case Hardener

A Compound Equal in Strength to 28/30% Sodium Cyanide

More economical than Lead owing to its lower specific gravity. Assures a clean heat. No oxidation.

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We advise the application of a

COPPER DEPOSIT through Electroplating

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COPPER CYANIDE SOLUTION

This process is specially recommended for gears, cam-shafts and similar articles, the copper film protecting the parts which are to remain soft.

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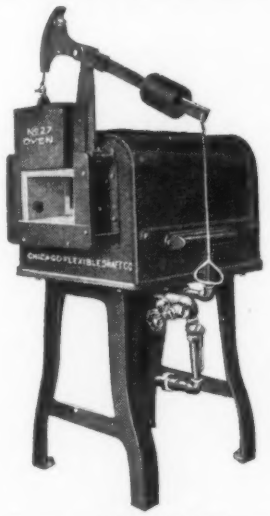
Quality in Furnaces



Stewart No. 27 Oven Furnace

For Hardening High Speed Steel, Pre-Heating for High Speed Steel Hardening, Annealing and Carbonizing.

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For Lead or Cyanide Hardening.

QUALITY production in heat treating operations is absolutely essential in these days. It is imperative that the heat treatment of expensive dies, gears, tools and machine parts be accurate.

Quality production is possible only in quality furnaces, practically constructed and guaranteeing uniformity and accuracy under the severest tests.

Stewart Furnaces guarantee quality production. Their scientific construction makes certain uniform temperature as long as necessary in every part of the heating chamber. Combustion takes place beneath the hearth, the flame surging over it and into the arch of the furnace, with maximum fuel efficiency. Burner placement guarantees uniform heat distribution, under instant and absolute control.

Manufacturers using Stewarts do not deal with an uncertainty — they know Stewarts guarantee high quality production at a considerable saving in time, fuel and material.

Stewart Furnaces have made a record for years of thoroughly satisfactory performance in manufacturing plants all over the United States and Canada.

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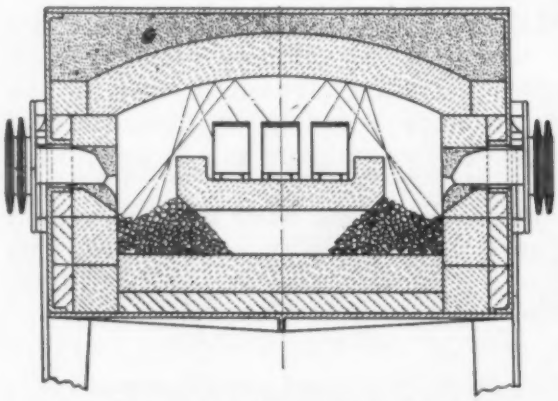

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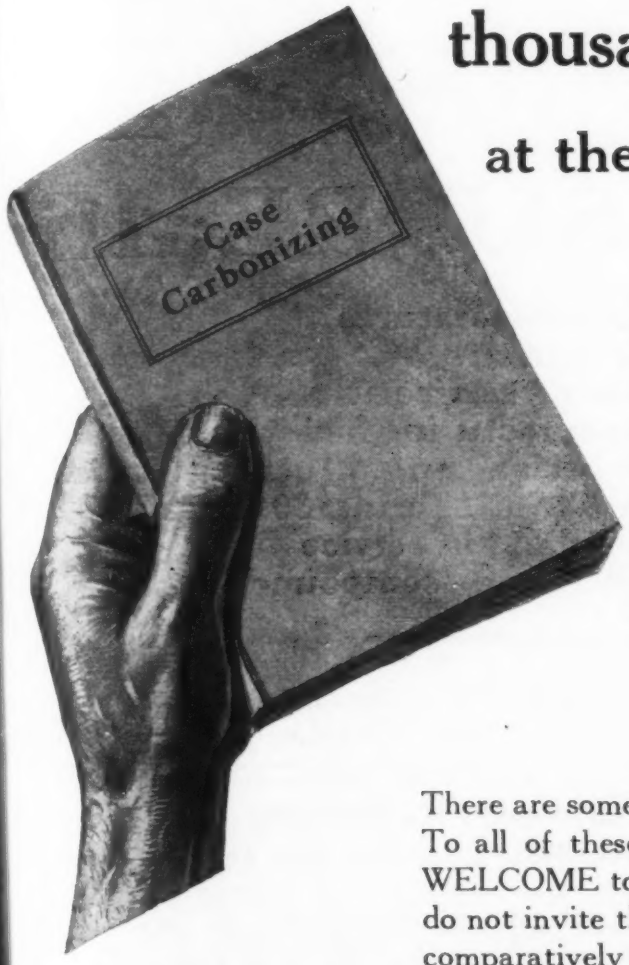

You may be one of them. If you're not, it's simply because we haven't become well acquainted. Men who know me say I have opened the way to greater carbonizing efficiency, so I must be **sound.**

* * *

There are some four thousand such men. To all of these we extend a HEARTY WELCOME to the Convention. But we do not invite them to another Book; the comparatively few remaining copies we wish to reserve for those who may not have received one as yet. So if you or your company already have a copy please do not ask for another.

But COME, visit with us and make the **Nichrome** Booth your own booth. There will be no latch string to pull; the door will be OPEN.

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The Best Heat Resisting Alloys Made Backed by a National Engineering Service

2200°F Q ALLOYS STAND-UP-UNDER-FIRE QUALITY

Sheets Castings for Pots & Boxes Special Shapes Cast or Fabricated

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Greater strength at higher temperatures
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Same prices and guarantees to all. Terms: 30 days net
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Q-Alloys are giving satisfaction in hundreds of plants throughout the country,—so much so that 80% of our 1921 business has been repeat orders. Our customers range from the smallest commercial heat treating plants to the largest users in the world. Fifty of them rate a million or over. Most Q-Alloy users have tried numerous alloys on test, but they are specifying Q-Alloys for production requirements.

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Q-Alloys comprised the largest exhibit at the Philadelphia Convention, occupying four booths. Nearly five hundred samples were given on request. These samples weighed less than 3 oz. and were $\frac{1}{8}$" in section with no cover;—metal exposed on both sides. The Diamond Chain Company advises that one of these boxes has run over 3,000 hours in a coal fired furnace. Figuring this on the basis of area exposed, a 1" cube of Q-Alloy, exposed to oxidation on one side, (like the wall of a carbonizing box), should run over 60,000 hours. We have received scores of similar reports.

If you are a Q-Alloy user, please call at our exhibit as soon as you arrive at the convention. We have special souvenirs, and several features, including complimentary automobile service, arranged for your special benefit.

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Over a dozen prominent manufacturers of steel products have contributed to make the Halcomb exhibit valuable to users of high speed, tool and alloy steels. Every man interested in fine steels and their uses can benefit by a visit to the Halcomb booths, 69-82. Below are listed a few of the exhibits shown.

Inserted tooth and disc saws, Dreadnought high speed steel

Cold-drawn high speed steel and its products

Punches, dies, gauges, Ketos non-shrinking steel

Automobile parts of electric alloy steels

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Magnet steel products, Stainless steel and its uses, Wortle drawing dies, ball wire and the making of balls hot and cold—and other equally interesting exhibits in the 400 square feet of booths 69-82—the first as you go in the door of the Exhibition building.

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To meet all S. A. E. Open
Hearth Alloy Specifications in

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Vanadium—Molybdenum—Chrome-
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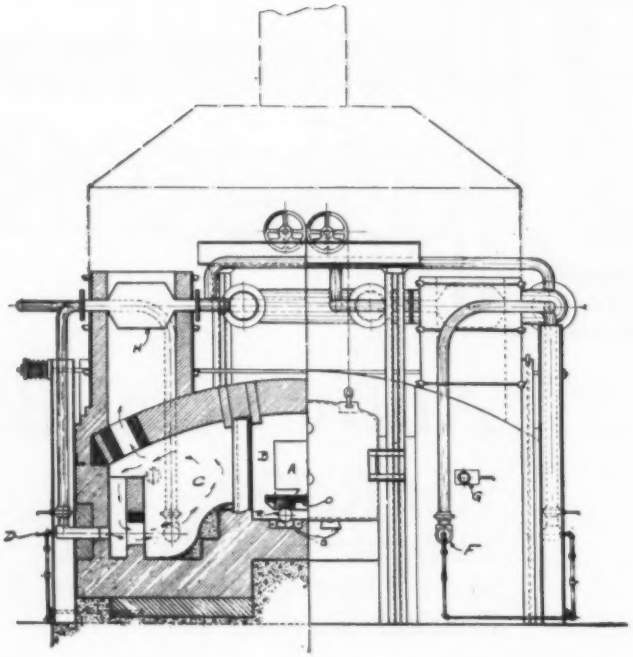

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If temperatures regulated as closely as 5° + or – will produce a more valuable product for you a furnace for doing this should be used. The most profitable furnace should be considered for each requirement. The above furnace is for treating die blocks at a regulation of 5° + or –.

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For Use At High Temperatures Are Made Of

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THE MOST ECONOMICAL HEAT RESISTANT METAL.

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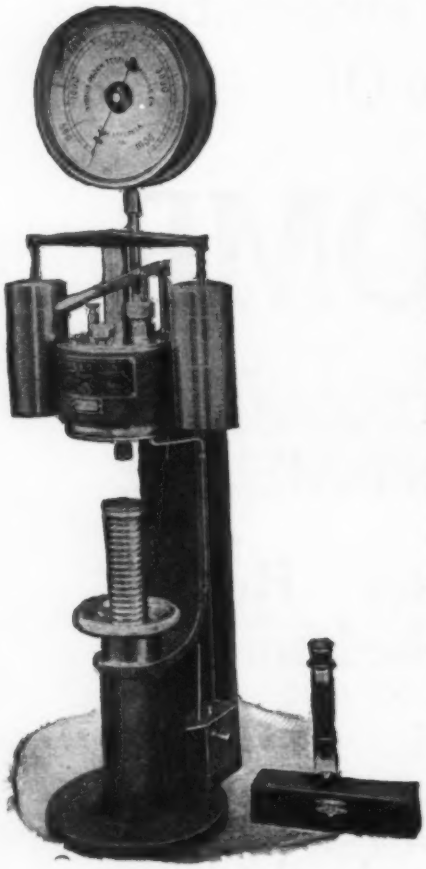
Olsen Testing Machines

All the latest up-to-date Testing Machines



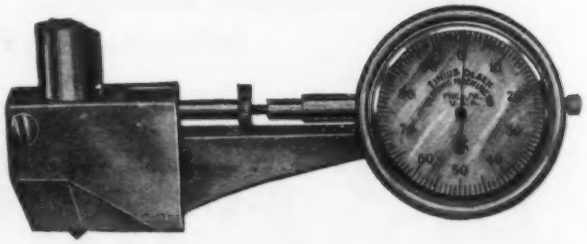
Olsen Hydraulic Brinell Hardness Testing Machine No. 1

This illustrates the very latest and most up-to-date type of Olsen Brinell Hardness Tester which is now used throughout the country by the leading automobile engineers and metallurgists who insist on securing the very best of Testing equipment.

This type of machine is made in several sizes and also of various types as per our Bulletin No. 1, which will be mailed on request.

Olsen Depth Measuring Instrument for use on Olsen Hydraulic Brinell Hardness Testing Machines

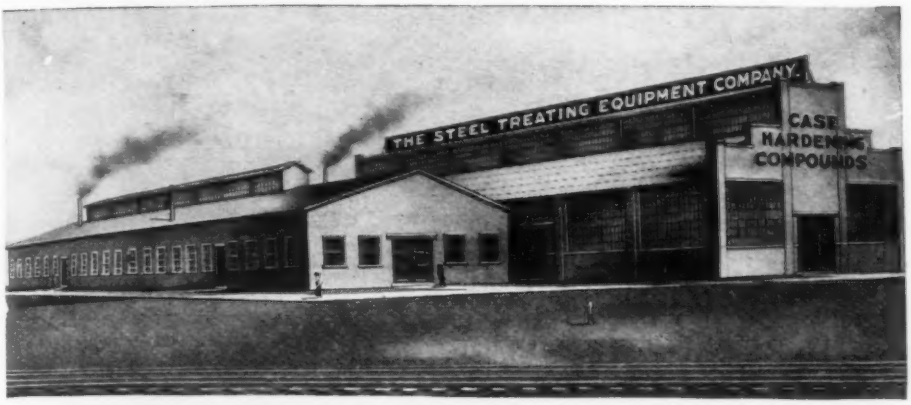
This illustration is of the very best and most accurate instrument made for measuring depth of impression and same can be attached to any Olsen machine in a minute's time.



Manufactured by

Tinius Olsen Testing Machine Company

500 North 12th Street Philadelphia, Pa.



Even as "the proof of the pudding is in the eating" so is a continued and constantly increasing demand for a product the best evidence that it is of high quality and gives lasting satisfaction.

The highest endorsement of

STECO

products lies in the demand which has made necessary the expansion from the small beginning of five years ago to the present plant shown above.

The Steel Treating Equipment Co.

Metallurgical Engineers

7945 Lafayette Boulevard West **Detroit, Michigan**

Planing Curved Armor Plate with tools made from Midvale Extra High Speed Steel

MIDVALE EXTRA HIGH SPEED STEEL

THIS brand of high speed tool steel was developed for severe cutting operations such as that illustrated above. It does our work. We know that it will do yours.

The test of every-day use is our best selling argument.

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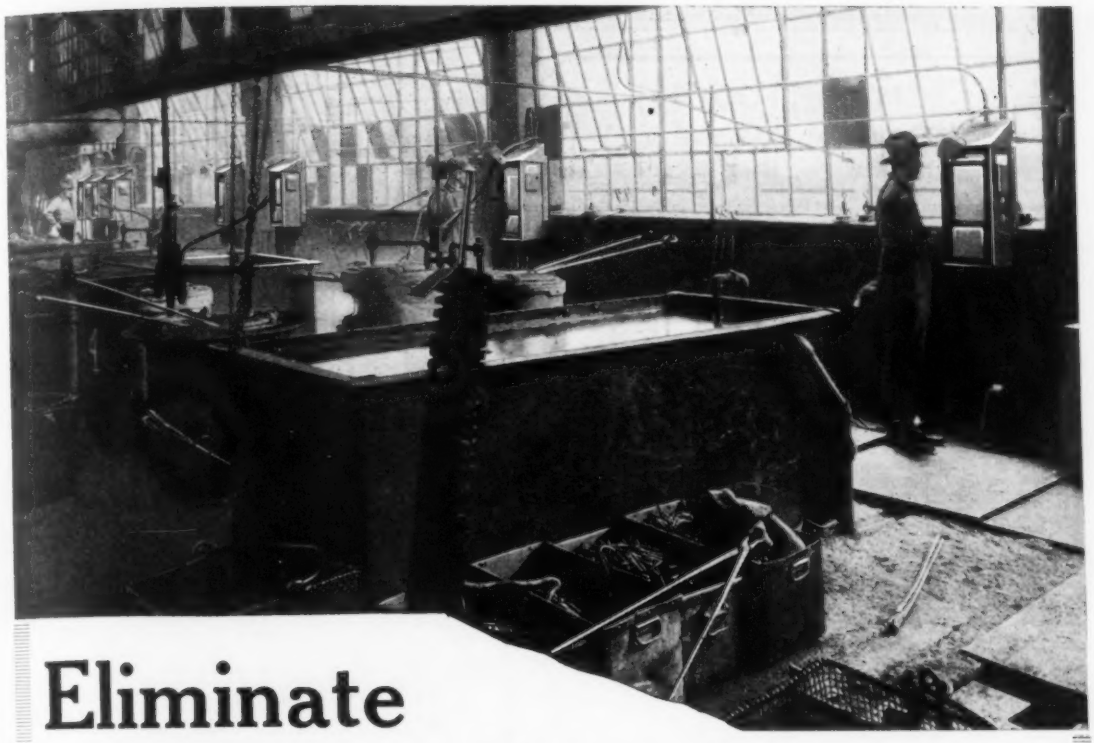
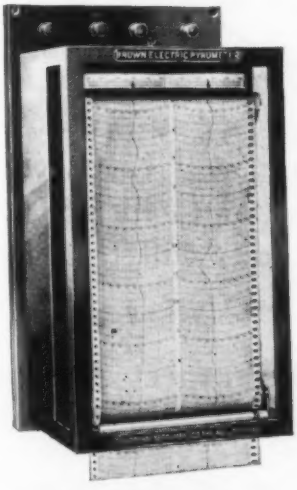


Eliminate

Poor Hardening-Distortion & Cracking

Let Every Man see his own Furnace Record



Brown Duplex Continuous Recording Pyrometer

Here is a shop where the temperature of probably as many as 80 lead pots are held between 1400 and 1500° Fahr. Not one of these pots, while operating, goes above or below this 100° range of efficiency. Poor hardening, distortion, and cracking, is absolutely eliminated, and the answer to this perfect heat treating is—every Furnace Man continually sees his own furnace record on the Brown Duplex Recording Pyrometer, located only a few feet away.

The plant shown above is one of the largest in the country and can avail itself of the best type of heat measuring instruments made. It chose Brown Duplex Recorders, because first, the thermo couple in each pot is connected with a millivolt system of its own—thus in case something should happen to a pot, other records are not affected, second, the record line is clear and easily read--no overlapping—just one record to each temperature scale, and two scales on every chart.

Write today for folder, 23-5, describing this installation in detail. There is no obligation. Address The Brown Instrument Company, 4502 Wayne Avenue, Philadelphia, Penna. or District Offices in New York, Chicago, Detroit, Cleveland, St. Louis, Pittsburgh, San Francisco, Los Angeles, Denver, and Montreal.

Brown Pyrometers

LIST OF TOOLS
and Grades of Colonial Steel adapted for their use

Name of Tool	Grades of Steel
Arbors	Red Star
Augers, Wood & Bits	Red Star
Axe	Red Star
Ball Bearings	Superior
Bits, Channeling Machine	Red Star
Bits, Coal Mining	Anchor
Bits, Tong	Red Star
Bits, Well Stone Drilling	Standard Wall Bit
Bush Hammer, Stone Tools	Red Star Sheets
Bunter, Heading	Red Star
Broaches, Machine	No. 7, High Speed
Bushings	Red Star
Center Punches	Red Star
Center, Lathe (see L)	Red Star
Chasers, Threading	H. S., No. 7, No. 14
Chain, Pipe, Links	Vanadium, Type A
Chisels, Pneumatic	No. 7
Chisels, Hand	Red Star
Chisels, Stone Cutters	Red Star
Chisels, Wood Working	Red Star
Cupping Tools	Red Star
Caulking Tools	Red Star
Claw Bars	Red Star
Creasers, Hot	H. S., No. 7 E
Counterbores	H. S., No. 14
Counterbores, Solid, Interchangeable	H. S., No. 7, No. 14
Collets, Bit Brace	Red Star
Collets, Spring	Red Star
Cutters, Fine Finishing	No. 5
Cutter, Pipe	H. S., No. 14
Cutters, Flue	No. 7, High Speed
Cutters, Flue Hole	No. 7
Cutters, Nail	High Speed
Cutters, Corn Stalk	Alto Sheets
Cutters, File	High Speed
Cutters, Milling, Plain	High Speed
Cutters, Form	High Speed
Cutters, Inserted Blade	High Speed
Cutters, Profile	High Speed
Cutters, Metal Slitting	High Speed
Cutters, Screw Slotting	No. 5
Cutters, Wood Forming	High Speed, No. 5
Cutting off Tools	High Speed
Dies, Bolt Threading	H. S., No. 7, No. 14
Dies, Blanking	H. S., No. 7, No. 14
Dies, Forming & Bending	No. 7, No. 14
Dies, Sub-Press	No. 7, No. 14
Dies, Drawing	H. S., No. 7, No. 14
Dies, Cartridge Shell	High Speed, No. 7
Dies, Hammer Dies, Power	Red Star
Flat Jack Jewelers' Dies	High Speed No. 7
Dies, Drop Forging	Red Star, Alto
Dies, Nail	High Speed
Dies, for Paper	H. S., No. 14
Dies, Pipe Threading	H. S., No. 7, No. 14
Dies, Solid & Adjustable Threading	H. S., No. 7, No. 14
Dies, Glove	No. 7, No. 14
Dies, Rivet	No. 7, Red Star
Dies, Shoe Knife	Red Star
Dies, Spring Screw, Threading	H. S., No. 7, No. 14
Dies, Solid Bolt	No. 7, No. 14
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Dies, Cold Heading	No. 7, Red Star
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Hammers, Nail Machines	No. 7
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Hobs, Gear	H. S., No. 7, No. 14
Header Dies, Cold	No. 7, Red Star
Header Dies, Hot	No. 36
Jaw Chuck	Imperial
Jaw Vise	Imperial
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Knives, Carver	Red Star Sheets
Knives, Butcher	Red Star Sheets
Knives, Cleavers	Red Star Sheets
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Knives, Heel Forming Shoe	No. 14
Knives, Shoe Makers	Red Star Sheets
Knives, Shoe Sole	Red Star
Knives, Surgical	No. 14
Knives, Table	Alto Sheets
Knives, Potato	Alto Sheets
Knives, Corn Knife	Alto Sheets
Knives, Drawing	No. 14, Red Star
Knives, Hog	No. 14
Knives, Machine	H. S., Red Star
Knives, Paper	H. S., or No. 14
Knives, Shear	No. 7, Red Star
Knives, Wood Working	H. S., Red Star
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Lathe Centers, Dead	Red Star
Lathe Center, Live	Red Star
Lathe Tools for Metal Turning	High Speed
Lathe Tools for Woodworking	High Speed
Liners for Brick Dies	Imperial
Letter Stamps, Hand	No. 7, No. 14
Letter Stamps, Roll	No. 7, No. 14
Mandrels	Red Star
Mills, End	High Speed
Mills, Hollow	High Speed
Mills, Shell End	High Speed
Piercers, Hot	High Speed
Pick Steel	Alto
Pinion Bars	Red Star
Pins, Drift	Red Star
Pinch Bars	Red Star
Planer for Metal Tools	High Speed
Planer for Stone	High Speed
Planer for Wood	Red Star
Point Steel for Stone Cutters	Red Star
Punches, Cartridge Shell	No. 7
Punches, Hand—Hot or Cold Work	H. S., or No. 7
Punches, Drawing	No. 7, No. 14
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Pneumatic Tools	No. 7E or F
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Rods, Piston	Red Star
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Reamers, Shell	High Speed
Reamers, Taper	High Speed
Reamers, Rose, Chucking	High Speed
Reamers, Locomotive, Taper	No. 14, H. S.
Reamers, Bridge	High Speed
Reamers, Expansion, Hand	High Speed
Reamers, Drill & Center	No. 5
Rolls, Flue Expanding	No. 7
Ring Gauges	No. 6, Oil Hard'ng
Rivet Sets	No. 7, Red Star
Shear Blades—Hot Work	H. S., No. 7
Shear Blades—Cold Work	No. 7, Red Star
Saws, Circular Metal	H. S., Nikro
Saws, Circular Wood	Nikro
Scrapers for Scraping Machine Parts	No. 5
Scrapers, Tube	Red Star
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Set—Rivet	No. 7, Red Star
Sets—Button	No. 7, Red Star
Sets—Nail	Red Star
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Shaper Tool	High Speed
Stamping Tools	No. 7, No. 14
Sledges, Blacksmith & Stone	Red Star
Snaps, Rivet	No. 7, Red Star
Springs	Red Star
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Swaging Metal	No. 7
Taps, Tapper	No. 14, Red Star
Taps, Hand	Red Star Tap, Extra No. 14
Taps, Machine	H. S., Red Star
Taps, Automatic Machine Screw	High Speed, No. 7
Taps, Staybolt	No. 14
Taps, Pipe Taps	Red Star
Taps, Pipe Tap Chasers	High Speed, No. 7
Tire Turning	High Speed
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Full instructions for hardening and tempering all Colonial Tool Steels will be found in the *Colonial Heat Treating Book.*
MAILED FREE.

in Cleveland—

THIS thriving city of varied manufacturing industries finds hundreds of uses for Tool Steels—and has shown a strong preference for the brands of Colonial.

And Cleveland is provided with most adequate facilities for the complete fulfillment of all Tool Steel needs.

The illustration shows the Cleveland Warehouse, carrying a big stock of Colonial Tool Steels, located at

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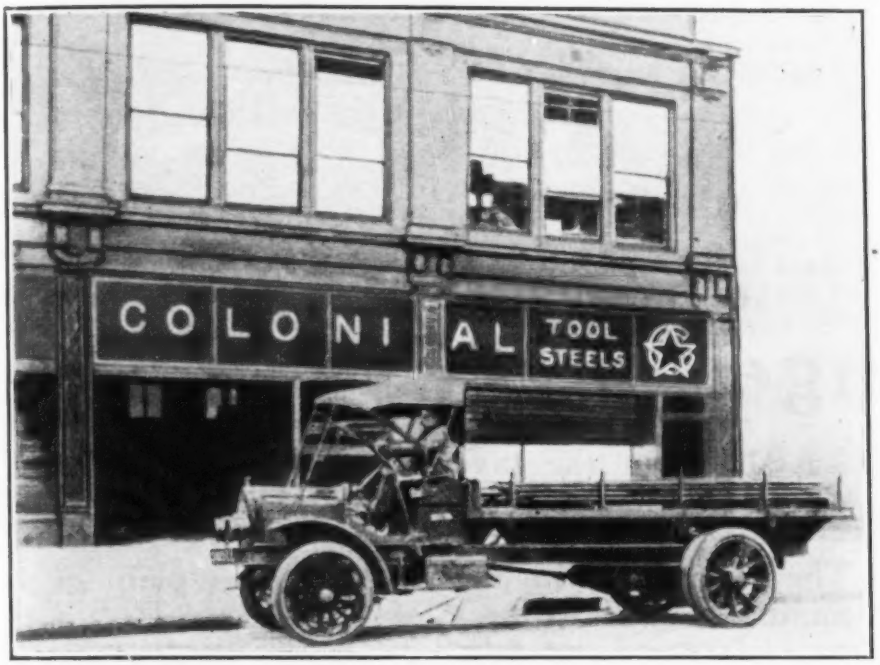
1104 Prospect Avenue
Telephone, 246 Prospect

Back of all this is the dependable performance that always has characterized Tool Steels bearing the brands of Colonial.

COLONIAL TOOL STEELS



A big stock of fine Tool Steels is here for your service

This uniformity has been a real aid to the Heat Treater. It has simplified his work, enabled him to foretell results accurately, and keep up his standard of making each job a success.

In Cleveland, and in any of the 8 other cities listed below, this high type of Colonial service in quality Tool Steels is immediately available to you.

Also, representatives in 11 other cities carry stocks of the Colonial brands. Their experience and judgment as well as their Tool Steels, are ready for your call.

Colonial Steel Company

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Toledo Detroit Chicago St. Louis

Do You Want Taxes Reduced?

Foolish question—of course you do!

Well, you can begin right now in your plant.

Have you any idea of the taxes you are paying in the form of lost time, extra fuel and spoiled product through not being able to know and control the temperature in your furnaces.

You can reduce these taxes by using pyrometers.

Engelhard Pyrometers

have reduced the taxes levied by guess work methods in many plants in your line.

They are built with the needs of your plant in mind and so are

Accurate
Strong
Dependable

And their users will tell you that their upkeep expense is so low that they are the economical pyrometer to buy.

Whenever you think of pyrometers remember that

Engelhard Pyrometers Are Good Pyrometers To Standardize On

Charles Engelhard, Inc.

30 Church Street **New York City**

Lower Your Heat-Treating Costs With Hoskins Electric Furnaces

IN THESE furnaces, ideally perfect heat conditions are approached. The right temperature is automatically held constant. Thus, the man at the furnace is doing nothing but actual productive work, under quiet comfortable conditions. He fusses with no valves. He can't help but turn out more work and better work, at less ultimate cost per pound.

Whenever pure air and steel are in contact with each other, there's sure to be some scale formed. But in Hoskins Furnaces, there's no continual in-rush of large volumes of useless air, and scale is almost entirely eliminated. That which is formed, is very thin and can almost be rubbed off. Because you do want lower costs, send for Hoskins Catalog No. 20 S. T.

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Volume 1 SEPTEMBER, 1921 Number 12

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4600 Prospect Ave.,
Cleveland, Ohio

E. F. ROSS, EDITOR

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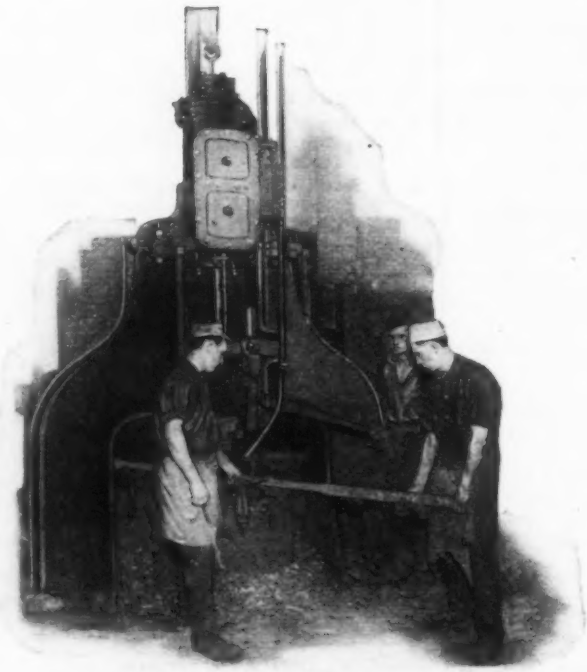

FINISHING CLARITE HIGH SPEED STEEL ON A 1400 POUND HAMMER. ALL MATERIAL IS HAMMER WORKED EVEN THOUGH ROLL FINISHED. THIS INSURES PROPER GRAIN REDUCTION.

A business cannot grow year after year with ever increasing thousands of customers unless there is some reason for it.

There is but one reason—its product fills the wants and needs. Perhaps a lot can be said of the achievements, but what is more than this?

Columbia Tool Steel is not the ordinary kind any more than is Columbia service—it costs you no more.

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In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

MECHANICAL ENGINEER—Age 33, married, 18 years experience as designer, machine shop foreman, chief draftsman, and efficiency engineer. Broad experience in designing of gas furnaces, special machinery, tools, jigs, fixtures, gauges and dies. Well acquainted with steel treating and hardening. Desires position where initiative and inventive ability along manufacturing lines are considered. Address 8-1.

SUPERINTENDENT OF TIME—In automobile plant. One year Govt. inspector on forge work, one year testing drop forgings and inspecting same, three years laying out forging machinery and taking time studies, also have taken time studies in assembling automobiles. Salary $300.00 per month. Address 8-2.

SALESMAN—Have had 6 years in chemical and physical laboratories of tool steel concerns. 3 years in charge of heat treating tool steels. No preference as to location. Wages $175.00 a month. Address 4-4.

WANTED—Position as assistant hardener. Practical experienced man in case hardening and heat treating of all different makes of steel. Do not claim to be an expert but can deliver the goods. Salary $25.00—$30.00 per week. Address 2-8

WANTED—Position as metallurgical engineer in technical, executive or sales capacity. Ten years practical experience in research, physical and chemical testing, pyrometry, metallography, inspection, and specifications. Have installed heat treating plants and laboratories. Address 2-5

WANTED—Position as metallurgist or assistant, graduate of University of Minn., one and one half years with large tractor company, covering heat treating, chemical, metallographic and physical testing, during that period. Chicago territory preferred. Salary $175.00 a month. Address 2-6.

WANTED—Position as salesman. Graduate of Carnegie Technical Institute. Student for 16 months with large steel company, Three years selling, Best of references. No preference as to location. Address 2-7.

GENERAL SUPERINTENDENT OR PRODUCTION MANAGER—8 years as general superintendent with large manufacturing firm. Expert on manufacturing firm arms and munitions, machinery and small interchangeable parts. Eastern location preferred. Address 4-1.

CHEMIST OR METALLURGIST—6 years as chemist and three years as chief chemist and assistant to the metallurgist. Cleveland location preferred Address 4-2.

SALESMAN—Selling steel or metallurgical supplies. Knowledge of Spanish, Willing to travel. Have been chief metallurgist for large Eastern firm. 7 years experience in heat treating of carbon, alloy and high speed tool steel, and general production work. Experienced in metallography, physical testing, pyrometry, and analysis. Best of references. Address 4-3.

POSITION WANTED—In metallurgical laboratory of heat treating room. 17 years practical experience in heat treating, specializing in tool hardening. No restrictions as to location. Reasonable salary. Address 8-3.

FOREMAN OR ASSISTANT FOREMAN—Practical, experienced in all around forging, blacksmithing and treating of steel. Experienced with tools used in shipyards and machine shops. Prefer location in Chester, Pa., Camden, N. J., or Philadelphia, Pa. Address 4-5.

METALLURGIST OR ASSISTANT METALLURGIST—College graduate. At present assistant metallurgist in large motor car company. Capable of handling heat treating, microscopic work, chemical analysis, and pyrometry. Desire Central or Western location. Salary $250.00 per month. Address 4-6.

METALLURGICAL ENGINEER—Young, capable, energetic, with 11 years experience. Graduate engineer. Bureau of Standards for 7½ years. Erie Forge Co. for 3 years. Expert in pyrometry in steel plant, forge shop, open hearth and heat treating plants, metallurgy, investigations and research, planning metallurgical operations, heat treating carbon or alloy steels, and management, forge shop temperature scheduling, etc. Salary desired $3000, or make your proposition. Answer 7-2.

METALLURGIST—Age 25, experienced in manufacture of steel from blast furnace to the finished, heat treated and tested product. Desire to form a connection with company now building up an organization where opportunity at present as the future shall predominate. Cleveland district preferred. Answer 7-1

SUPERINTENDENT OF HEAT TREATING—Have had 12 years' experience as blacksmith and in heat treating. At present in charge of same in large automobile plant. Have installed equipment, and have some experience along mechanical lines. During war in charge of aircraft forging, heat treating and as metallurgist. Salary desired $3600. Answer 7-1.

MEN AVAILABLE

HEAT TREATING FOREMAN—Two years pyrometrical and heat treatment of gun forgings; one year heat treatment and physical testing of rolled bar stock, and simple analysis; 1½ years heat treatment, carburizing, and hardening of automobile forgings. Address 9-5.

FOREMAN: 30 years practical experience in heat treating, forging tool hardening, carbonizing. 5 years as foreman of heat treating. Location preferred in Pennsylvania, New Jersey, or Maryland. Salary desired $200 per month. Address 9-3.

METALLURGIST—CHEMIST—Former member chemical engineering staff of University of Michigan; chief metallurgist Packard Motor Car Co.; metallurgist drop forge company. Address 9-1.

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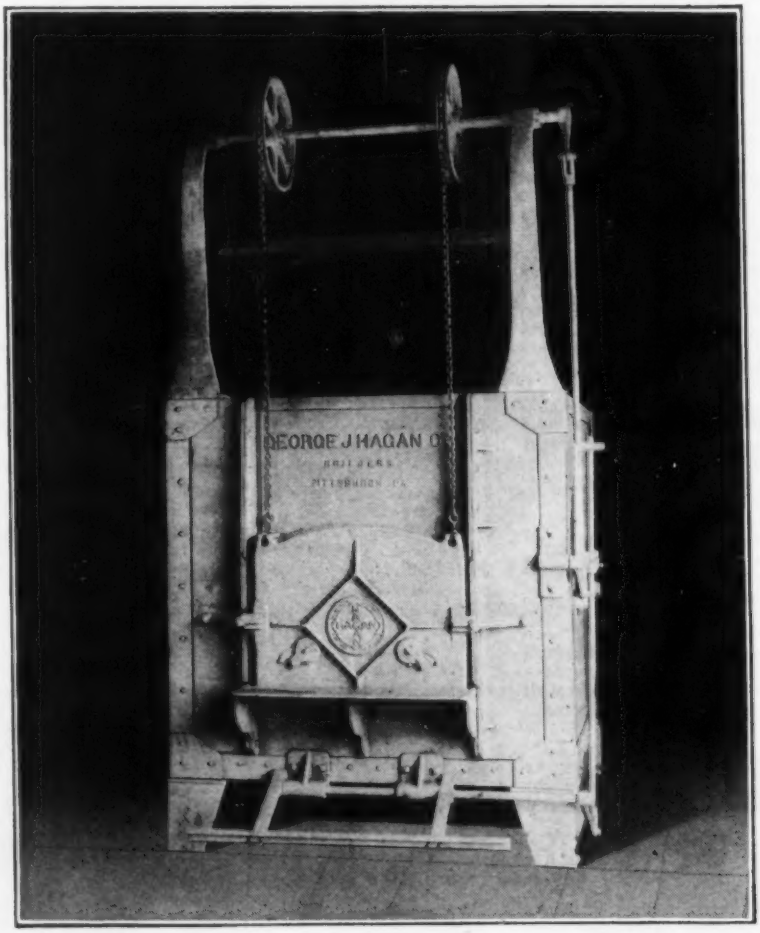
STANDARDIZED HEAT

ELECTRIC TYPE

Standard width of door 24", 33", 42". Standard lengths from 36" to 121". Furnaces of these sizes are shipped completely assembled and ready for operation. Furnaces larger than 121" are shipped "knocked down" and erected in purchasers plant.



For circular on Electric Furnaces ask for *Bulletin EF-4*

HAGAN — INDUSTRIAL FURNACES FOR ALL PURPOSES

Hagan Standardized Electric Heat Treating Furnace Complete Automatic Control

It's a WAYNE Furnace

The name *Wayne* on an oil-burning furnace for forging or welding means that its design is based on scientific principles that assure perfect combustion of oil, quick, even heats and minimum fuel consumption.

The oil burning furnace illustrated above is specially designed for forging, welding, bulldozing, dressing of tools, heating drill steel, etc.

Any size or type of this furnace may be equipped with either Wayne Adjustable or Non-Adjustable Type Oil Burner or Combination Gas and Oil Burner for use with either high or low pressure air.

Send for Bulletins 3215 ST, 2520 ST, 2556 ST.
You'll find them very interesting and valuable.

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A national organization with offices in thirty-four American cities. Canadian Tank and Pump Co., Limited, Toronto, Ont., Can. Representatives everywhere. Repair stocks and expert service at your command.

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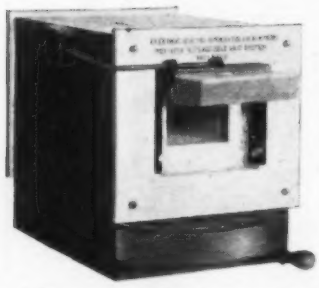
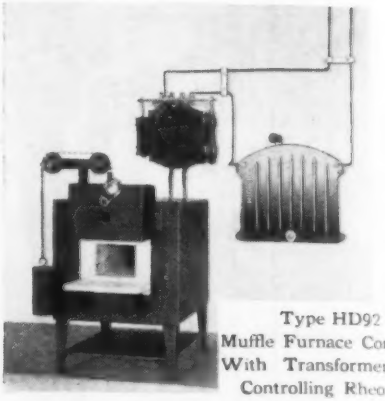
Small Furnaces

For Laboratories, Instrument Manufacturers, Tool Shops, Etc.

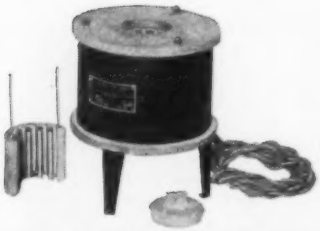
Temperatures up to 2000° F.



Incased-Rheostat Muffle Furnace—Types 60, 62, 64 and 66. Door, Shown Top-Hinging, is Reversible for Bottom Hinging



Type HD92 Muffle Furnace Complete With Transformer and Controlling Rheostat



Crucible Furnace, Types 80, 82, 84 and 86—Shown with One Spare Unit

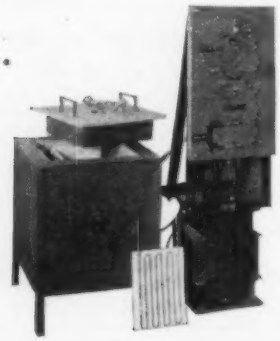
This form of furnace is used extensively for melting small quantities of base metals; for pyrometer calibration when couples are immersed in molten salts or metals; and for decalescent work in steel.

Standard Combustion Tube Furnace Type 77

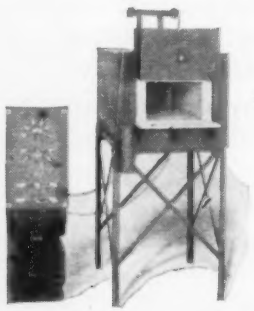
Shown with one spare unit, height to center 10"

Combustion Furnace, Hinged Design Type 70

Shown with one spare unit, height to center 9½"



Type HD710 Crucible Furnace with Regulating Transformer



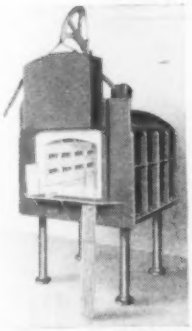
Type HD122 Muffle Furnace Complete with Regulating Transformer

Westinghouse

Large Hevi-Duty Industrial Furnaces

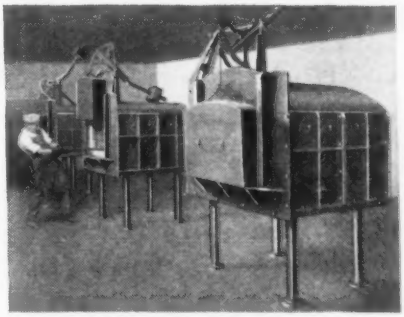
For Any Kind of Heat-Treating Process

Any Size — Any Capacity — Temperatures up to 2000° F.



Type HD2631
Single End, 25 x 16 x 36'

A six-strand return bend coil placed in three muffle plates shown on floor, leaning against shelf of furnace. At the left on furnace shelf is shown grooved muffle plate. Also on the shelf is shown a Tee-support. These return-bend coils, muffle plates and Tee supports are typical of all catalogued sizes. Two muffle plates, each 12 inches long, comprise the length of the 24-inch furnace; three muffle plates in the 36-inch furnace; four in the 48-inch furnace.



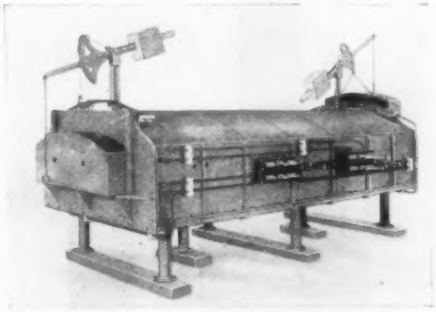
Battery of Industrial Types of Furnaces (Standard Sizes.) From Left to Right Respectively, Types HD1321, HD1331 and HD2631

Figure the Guaranteed Efficiencies at Your Operating Temperature, and Compare Operating Costs With Any Other Furnace—Oil or Electric, on the Market

Type	Style	Inside Dimensions Width	Length	Height	Rising to 1800 Deg. F. K. W. From Room Temperature Full Load	Time	K. W. Hrs.	K. W. per Hour Holding at 1400° F.	1600° F.	1800° F.
HD1321	Single End	18	24	13½	22.66	3⅓ hr.	75.5	3.8	4.5	6.2
HD1331	Single End	18	36	13½	29.88	3¼ hr.	97.1	4.3	5.7	7.4
HD1341	Single End	18	48	13½	40.60	3¼ hr.	131.9	4.7	6.1	8.2
HD1361	Single End	18	72	13½	57.75	3¼ hr.	187.7	6.4	8.2	11.0
HD2631	Single End	25	36	16	35.86	3⅓ hr.	119.5	5.1	6.7	8.5
HD2641	Single End	25	48	16	48.72	3⅓ hr.	162.4	6.4	7.9	10.4
HD2661	Single End	25	72	16	69.30	3⅓ hr.	231.0	8.5	10.3	13.8
HD3641	Single End	32	48	16	56.84	3¼ hr.	184.7	7.4	8.6	10.8
HD3661	Single End	32	72	16	80.85	3¼ hr.	262.8	9.9	11.7	15.1
HD1362	Double End	18	72	13½	57.75	3⅓ hr.	192.5	7.4	10.4	13.7
HD2662	Double End	25	72	16	69.30	3½ hr.	242.5	10.0	12.0	15.7
HD3662	Double End	32	72	16	80.85	3⅔ hr.	296.5	11.7	13.8	17.8

Westinghouse Electric Furnaces

See our Exhibit at the September Convention



Double-End Furnace, Inside Dimensions, 44 in. Wide, 12 ft. Long, 6 in. High to Spring Line of Arch, 10 in. to Center of Arch, Capacity 120 Kilowatts.

Westinghouse Electric & Manufacturing Company

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Westinghouse

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(Successors to Swedish Iron and Steel Corporation)

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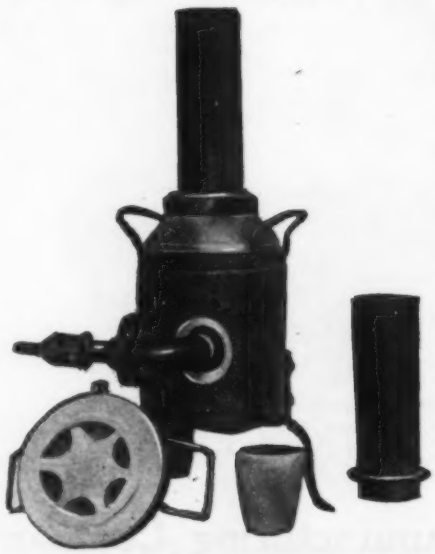

For brass, nickel, copper, iron, gold, silver, palladium, alloys, etc.

We supply crucible furnaces of various sizes attaining temperatures up to 1750° C. and muffle furnaces up to 1650° C.

Write for Meker Bulletin.

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(The Master Alloy)

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Forgability
Ease of Heat Treatment
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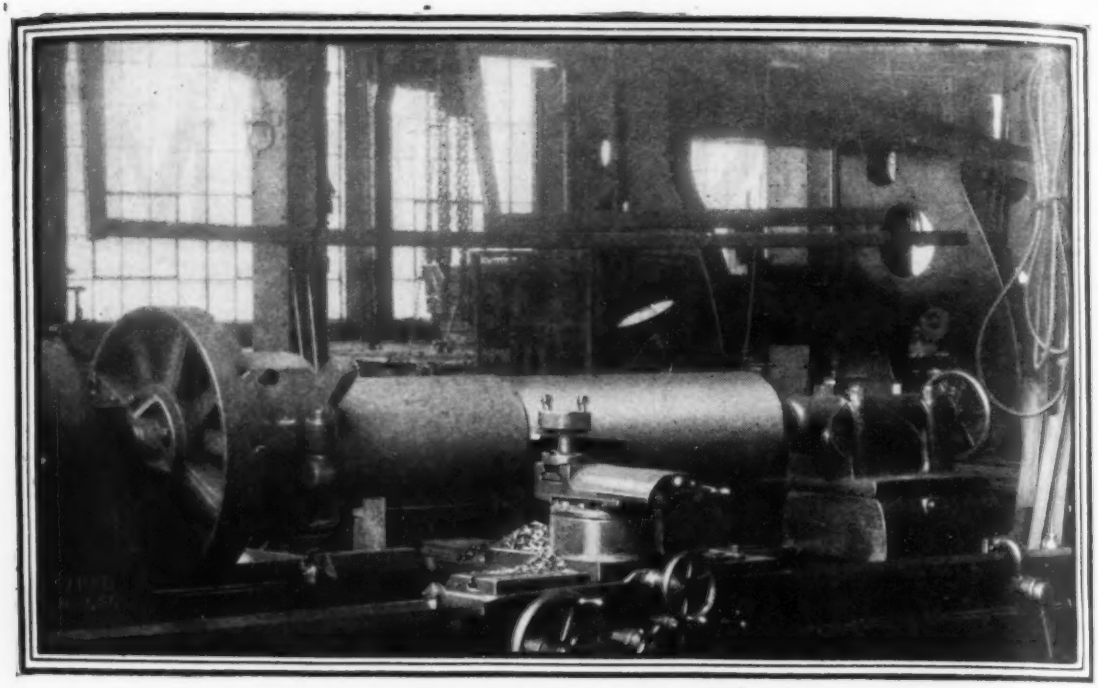
Toughness
Resistance to Shock and Fatigue

Vanadium Corporation of America
120 Broadway **New York**



A big saving with a little Stellite

THE small piece of Stellite on this big tool proved to be far more effective than a solid tool of any other cutting metal. Tool cost was cut considerably and 8 to 10 minutes saved on the first roughing cut taken on the O. D. of the above Radial Drill-Press Column Sleeve. Stellite's enduring hardness accounted for further saving, since other tools required sharpening three to five times as often.

This shop was quick to see the advantages of standard Stellite Welded-Tip tools which made the following clean-cut gains:

	Other Tools	STELLITE
Cutting Speed (ft. per min.)	75	100
R. P. M.	18	25
Average Cutting Time	30 min.	20 min.

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WELDED-TIP TOOLS
Remove More Metal at Higher Speeds

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is the consistently uniform high speed steel that may be depended on absolutely for the rapid cutting of any machinable metal.

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Used Only for Quick Case Work

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Resistance Type Electric Heating Devices, including Electric Ranges, Steel Treating Furnaces, Enameling Ovens, Immersion Heaters, and Laboratory Equipment.

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The Electrical Refractories Co.

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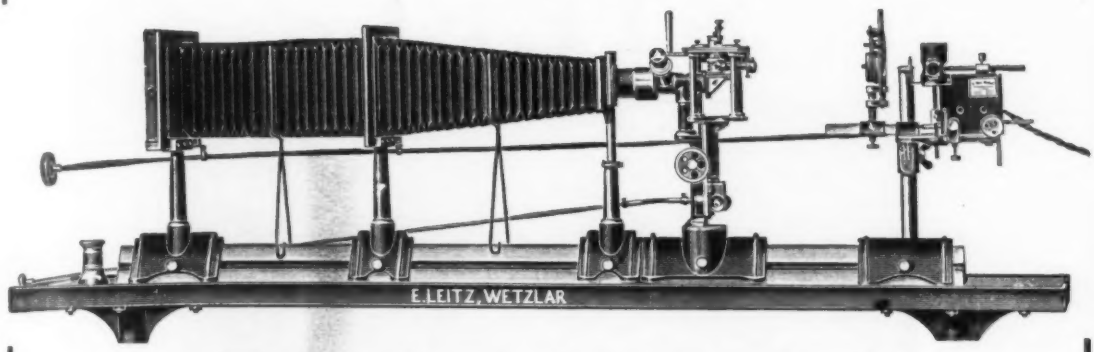
Our Refractories are used by the largest manufacturers of electric heating devices both domestic and foreign.

Leitz "Micrometallograph"

Large Metal Microscope with Camera



This apparatus is the only metallurgical equipment which received a distinct recognition at the Panama-Pacific International Exposition, due to its merits and efficiency.

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Achromatic Objectives for routine investigations.

Semi-Apochromatic (Fluorite) Objectives for routine and advanced investigations, also micro-photography.

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Ask for Pamphlet No. P-1000 and descriptive Booklet.

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We recommend our cold melt and highly refined electric alloy steels wherever high resistance to dynamic stress under conditions of severe wear and unfailing service is required.

We Develop Steels Required
For Particularly Hard Usage

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is being obtained in those plants using KINITE. Here are some of the results as reported to us:—

Article	Operation	Pieces per dressing of tool	
		KINITE	Other Steel
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Coffee Pot p 4-qt. 4th Oper.	Draw	10,000	650
Tin Can Top	Blank and Draw	2,000,000	300,000
Galvanized Clamp, ⅛" Stock	Blank	75,000	15,000
Engine Oil Pan—black steel	Draw	101,000	5,000
Pressed Steel chassis channel	Shear	16,000	800
Bracket, ¼" Stock	Blank	130,000	8,000
Journal Box Covers	Hot Form	250,000	18,000
Oil Stove Wick Raiser	Draw	30,000	3,500
Oil Stove Burner	Draw	26,000	3,000
16 Gauge Steel Shell, 13" diam. 23" deep	Draw	4,500	325
Circular Trimming Shears	Trimming	450 Gross	150 Gross

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JEFFRIES AND ARCHER published their epoch making work on "The Slip Interference Theory of the Hardening of Metals" in Chemical & Metallurgical Engineering for June 15, 1921.

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Blaich Modern CARBONIZERS

Embody the following fundamental features in their construction and performance—

High Efficiency — Stability
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and are now employed by many of the largest manufacturers of automobiles, trucks, tractors, auto parts, and special machinery in the United States and Canada, who insist on high quality of material backed by good service, at a reasonable cost.

The efficiency of these materials is marked by the ability to produce rapid penetration of carbon at the usual carbonizing temperatures, and to meet the most exacting demand, for a "case" of the proper carbon content and zone gradation.

The inherent high quality and uniformity of "BLAICH MODERN CARBONIZERS" is due to the use of only the very highest grade of all the materials used in their manufacture and to the careful, and scientific compounding of them. The proper balancing of all the elements essential to the manufacture of these carbonizers, coupled with the most modern mechanical equipment and years of experience, guarantees products that cannot be excelled for uniformity.

Their stability and economy is evidenced by the strength they display in re-employment, resulting in unusually long life and service, which, combined with their light weight per cubic foot, makes these carbonizers the most economical case hardening materials on the market.

Let us ship you a sample of carbonizer, gratis, to test its merits in your own plant. Others have tried it and been convinced—why not you?

CHARRED LEATHER—For heat treating and mottling purposes
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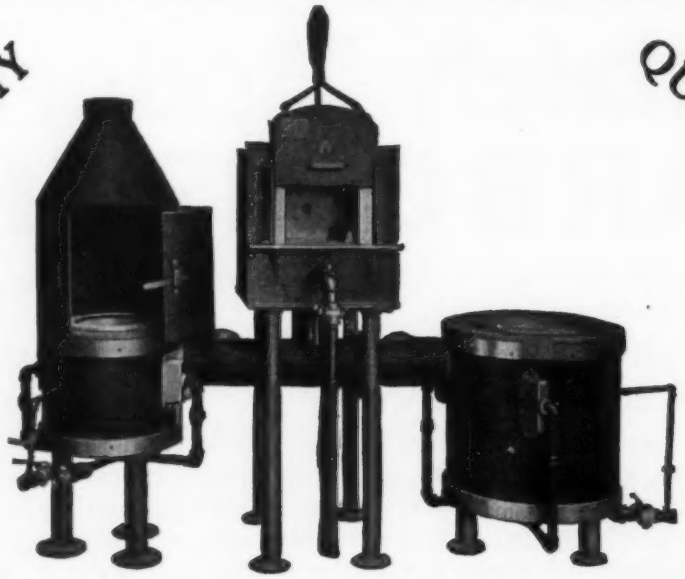

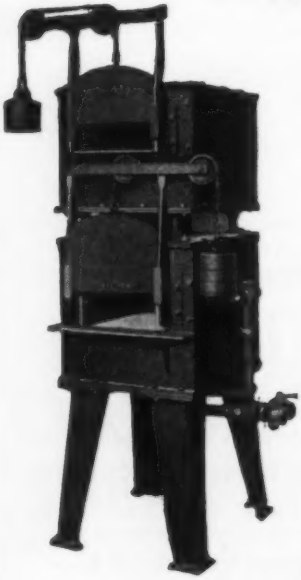

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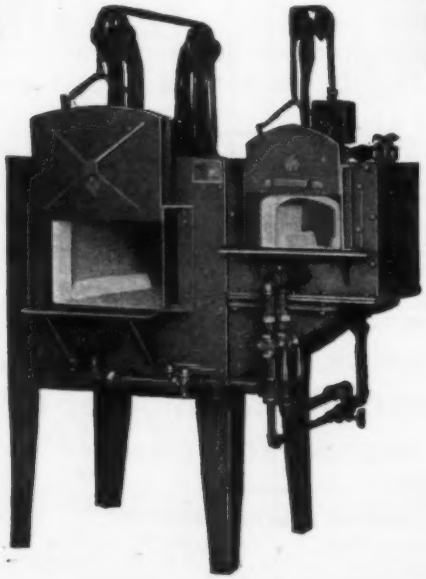

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"RedCut Superior"

THE NATIONALLY KNOWN—FIRST QUALITY
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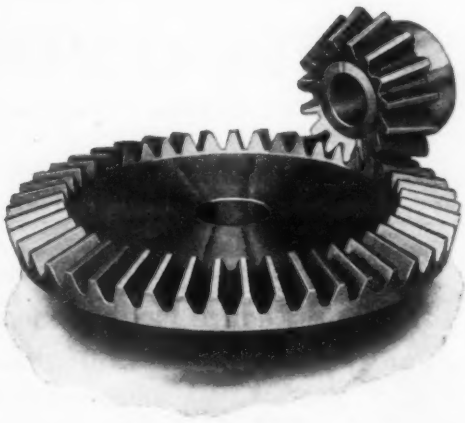
GEARS



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Silent Chain
Sprockets
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Rawhide
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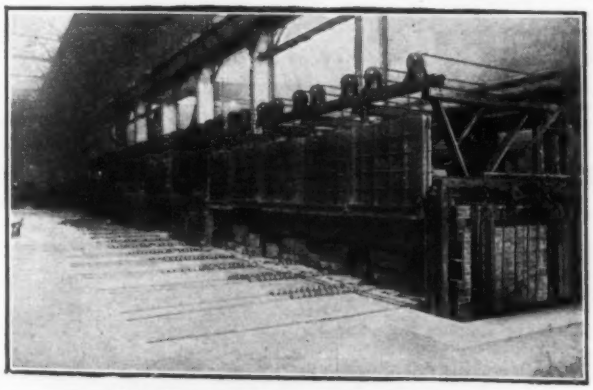

Side-Opening Heat-Treatment Furnace
105 ft. wide and 5¾ ft. long

The Furnace, underfired with oil or gas, is used for the heat-treatment of material ranging from die blocks to shafts 100 feet long.

It can be divided by movable partition walls into a number of sections. Each section may be heated separately or, after removing the partitions, in conjunction with any or all of the others.

Complete details are given in Bulletin 222-C.
Write for copy to nearest branch.

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Furnace Engineers and Contractors
50 CHURCH ST. (Hudson Terminal Bldg.) NEW YORK

WE MAKE INDUSTRIAL HEATING FURNACES FOR EVERY REQUIREMENT
COAL—OIL—GAS—ELECTRICITY
"FURNACE AND FUEL TO SUIT CONDITIONS"

BRANCHES: Chicago, Ellsworth Bldg. Cleveland, Engineers' Bldg. Detroit, Majestic Bldg.

W.S. ROCKWELL CO. INDUSTRIAL FURNACES NEW YORK

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Reduce Heat Losses

Protect your furnaces and other heat equipment with ***SIL-O-CEL*** insulation. It prevents penetration and radiation of heat and saves fuel.

Write for Bulletin P-8

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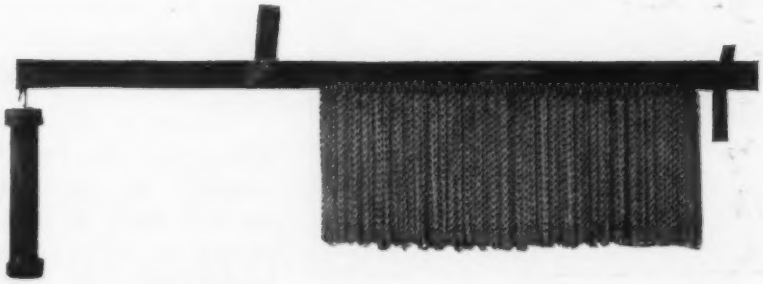
THE NEW PIVOTED

Chain Furnace Screen



Heat and glare from the opened furnace lessen the efficiency and the keenness of eyesight of

"The Man at the Fire"

A flexible, penetrable, movable curtain of chain holds the heat in the furnace, while not interfering with the view or handling of the charge.

700 S. Caroline St. E. J. CODD CO. Baltimore, U. S. A.

"The Man at the Fire"

There are some who forget what experience means,
(They are generally fellows just out of their 'teens)
And by using pyrometers seem to acquire
A lack of belief in—
"The man at the fire."

They'll talk of "calescence" and "pearlite", and tell
You the value of "cementite":—(sounds very well!)
And the depth of their learning will make you perspire,
But they don't get *results*, like—
"The man at the fire."

A pyrometer's good when it's kept in its place,
But sometimes you'll find there's a lie on its face,
And then when the heat's climbing higher and higher,
The man who can *tell*, is—
"The man at the fire."

Now do not mistake me; I say, by all means
While you're lacking in skill, put your trust in machines;
But if to be really expert you aspire,
Then study, as well, with—
"The man at the fire."

So when you are learning your job, never heed
Those who tell you that skill is a thing you don't need;
For skill and hard work you will surely require,
If you hope to compete with—
"The man at the fire."

By L. GERALD FIRTH
Works Manager
Firth-Sterling Steel Company
McKeesport, Pa.
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What Do You Know About the Heat Treatment of Steel?

A Booklet You Should Read

WHAT is the "decalescence" point in the heat treatment of steel? What is the "recalescence" point? Do you know the proper hardening temperature for high speed steel?

All of these points are discussed, and much other valuable detailed information is given, in a treatise entitled "The Cooling of Quenching Oil in the Heat Treatment of Steel," which has just been published by The Griscom-Russell Co., 97 West Street, New York. Any executive may obtain a copy free of charge by writing for it on his own or on his company's letterhead.

The first of the three principal operations in the heat treatment of steel is HARDENING, or quenching, and is the operation of quickly plunging steel, which has been heated in a furnace to a point above its critical temperature, in a cooling bath of brine, water or OIL.

The effect of quenching is to arrest or fix by rapid cooling certain changes in the internal structure of the steel which occur when the temperature passes above the critical range.

Modern practice provides for continuous rapid circulation of the quenching oil and for cooling external to the tanks. The engineering and designing staffs of The Griscom-Russell Co., after having devoted years of study and experiment to this problem, finally perfected the Multiwhirl Oil Cooler. Some of the advantages of this cooler are as follows:

(1) Patented Helical baffle—long smooth oil path—minimum pressure drop. (2) Tube bundle removable—facilitating inspection and cleaning. (3) Tubes expanded into tube plates—no sweated joints. (4) Floating head construction—no expansion strains on tube joints. (5) Outside packed head—this construction eliminates any possible leakage of water into oil, through faulty packing. (6) Compactness of unit—this is permitted by the high rate of heat transfer secured in the Multiwhirl Cooler. (7) Installation in any position—the Multiwhirl Cooler may be installed in any position with equal efficiency.

The following organizations are a few of those who have adopted Multiwhirl Coolers for cooling quenching oil.

Cadillac Motor Car Co., Packard Motor Car Co., Ford Motor Co., Nash Motors Co., Hyatt Bearings Division of General Motors Corporation, American Auto Parts Co., American Fork & Hoe Co., Ingersoll-Rand Co.

If your industry touches the heat treatment of steel do not fail to write for a copy of the treatise.

Lead Pot Carbon

Attention:— Users of LEAD POTS

We really have that charcoal substitute you have long desired for covering lead pots.

As the name implies, it is a carbonaceous material.

Its action is not mechanical, but as a reducing agent, it prevents the formation of slag or scale.

It acts similar to charcoal, namely a product yielding enough gas to assure a continuous reducing atmosphere over the surface of the pot.

Its first cost is less than charcoal and its life on molten lead is many times longer. In fact, a layer an inch thick uniformly spread over the bath will last from three to five hours.

It is not as dusty to handle as charcoal.

Try it and become one of our steady customers.

We are also manufacturers of

Woodside's Rapid Carbonizers—Cyanide Hardening Compounds—Klean Heat—Quenching and Drawing Oils

PARK CHEMICAL COMPANY

DETROIT, MICHIGAN

CARBO

CASEHARDENING COMPOUND

Tracing Results

Through Nuttall Registered Gears

Every NUTTALL Gear is stamped with the NUTTALL name, date and number. A permanent record is kept of the steel analyses and heat treatment, as well as the strength, the hardness and the toughness of the steel after treatment.

Thus the NUTTALL Company is able to trace back to, and to remove the offending cause if found in the manufacturing process.

These records have enabled the NUTTALL Company to confirm its high opinion of CARBO. CARBO has been used in the Nuttall factories for more than ten years.

Nuttall metallurgists will tell you that their preference for CARBO is based on long life, low shrinkage and uniformity of results—an opinion arrived at after many years' experience and exhaustive tests of casehardening materials.

The Rodman Chemical Company

Verona, Pennsylvania

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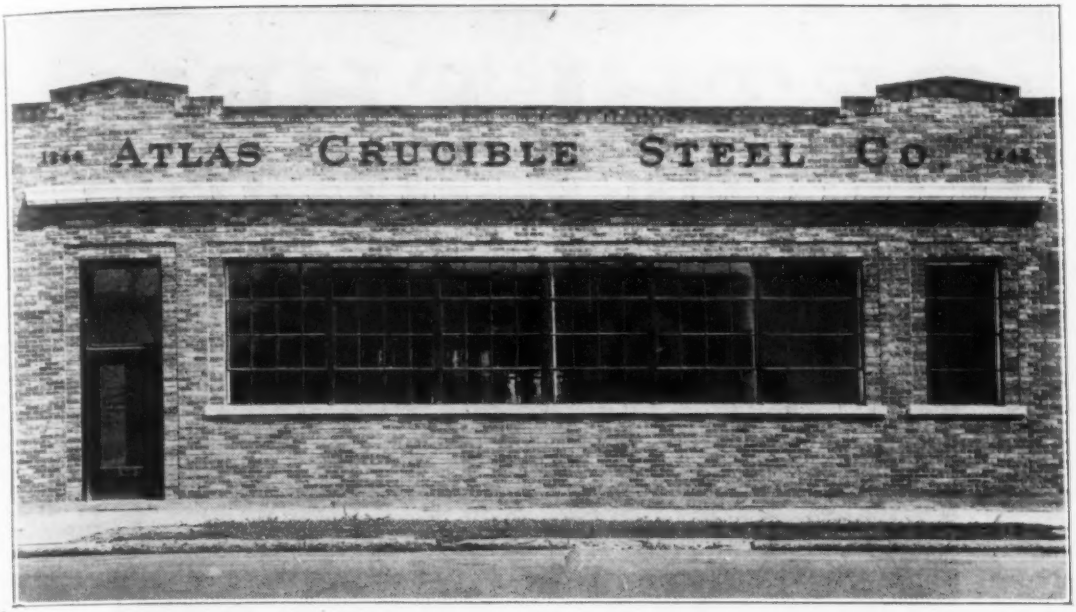

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WITH the stocks carried at the mill and also at Chicago, Detroit, Cleveland, Boston, San Francisco, Toronto, and Montreal, we are in a position to render prompt and efficient service on the various ATLAS Products.

Some of our well known brands are:

L-XX High Speed Steel Drop Forgings

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Atlas Extra	**Atlas Magnet**
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We operate our own wire mill where we make High-Speed and Carbon Drill Rods and also draw the different grades to various shapes and sizes.

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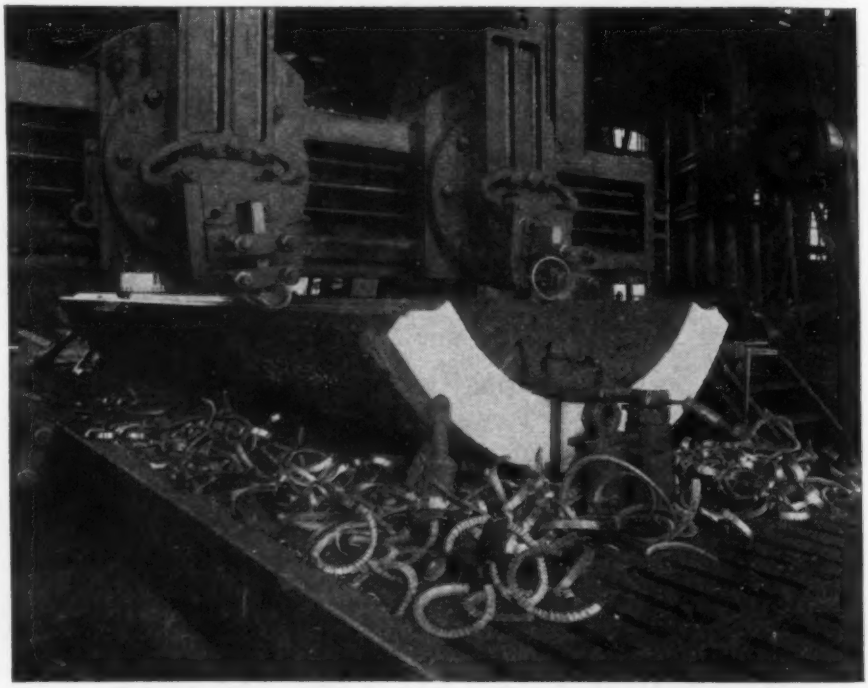
BETHLEHEM
Special High Speed Tool Steel



Illustrated above is a roughing tool made of Bethlehem Special High Speed Tool Steel taking a heavy cut on a section of an armor plate conning tower tube. The remarkable performance of this tool will be of interest to all users of tool steel:

Size of Planer	10 ft.
Size of Tool	2½ in. x 3½ in.
Cutting Speed	18 ft. per min.
Depth of Cut	1 in.
Feed	¼ in.

Bethlehem High Speed Tool Steel is recommended for lathe, planer, boring, slotting, shaping and other roughing tools, and for twist drills, milling cutters, taps, reamers, gear cutters, inserted saw teeth, inserted milling cutter teeth, and special dies.

Tool Steel Catalogue on Request

BETHLEHEM STEEL COMPANY

General Offices: **BETHLEHEM, PA.**

Sales Offices:

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SOLE EXPORTER OF OUR COMMERCIAL PRODUCTS CONSTECO CONSOLIDATED STEEL CORPORATION 25 BROADWAY, NEW YORK, U.S.A.

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Convention and Exposition
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Manufacturer's Building
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76,800 sq. ft. of exhibits. **Plan to Come.**

Everybody will be there.

HARDNESS TESTING
Is Now Done Almost Exclusively With
The SCLEROSCOPE
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Direct reading, can be operated by anyone with great rapidity. Measures softest metals and hardest steels without adjustment. Send for our booklet, free.

The PYROSCOPE
as a heat indicator, has solved the most difficult problems. In heat treatment of steel, forging, founding, etc.
Unexcelled for constancy, inexpensive.
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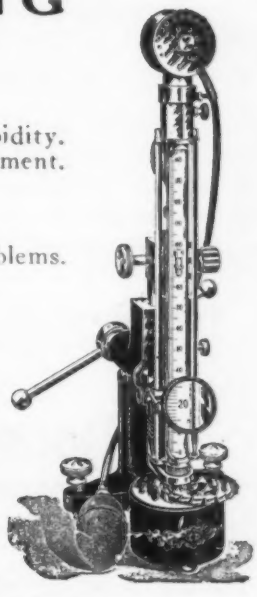
Selective Carburizing Localized Hardening By SHORE Process



Shore Instrument & Mfg. Co., Inc.
Van Wyck Ave. and Carll St., Jamaica, N. Y.
Agents in all Foreign Countries

Bausch & Lomb Metallographic Equipment

A complete Metallographic Equipment, for determining the physical nature of metals and alloys, has become a recognized necessity for every industry maintaining a control laboratory.

Bausch & Lomb Metallographic Outfits are extremely rigid and have ample range of adjustment, making them very convenient to handle. This optical equipment is of the highest standard, illumination is under perfect control and the results obtained are clear and sharp.

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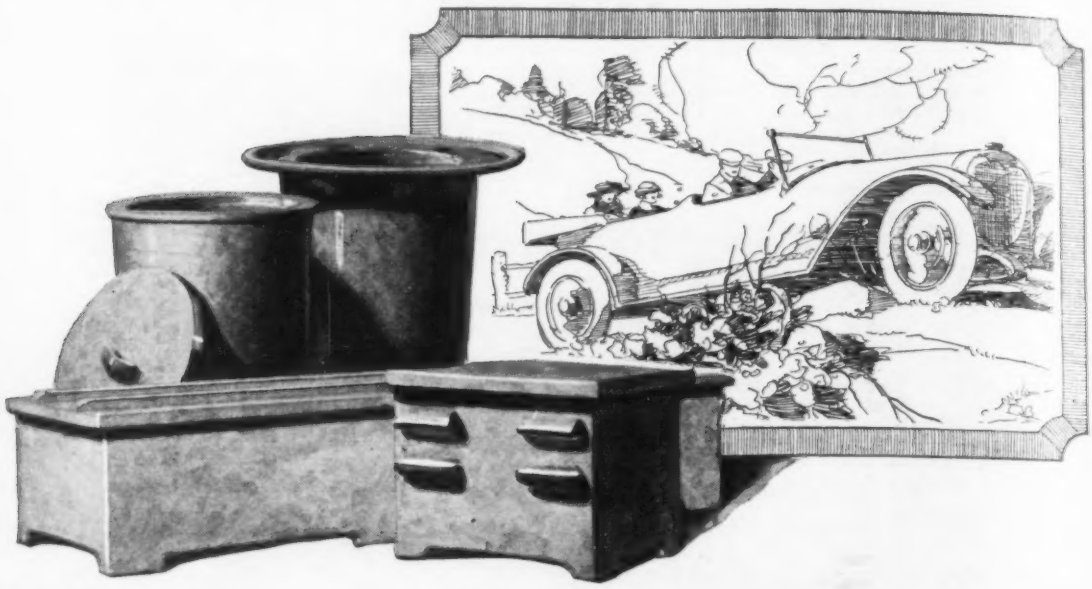


Which is of Greatest Importance to YOU— *Quality or Economy?*

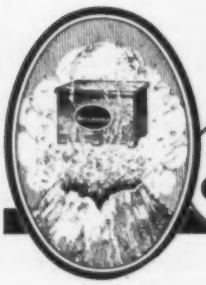
Pretty hard to say; isn't it? In the final analysis quality and economy are mighty close to twin brothers, and both must be measured in terms of service.

How well the case-hardened part performs its function, on an average, depends on how the various elements in the carbonizing process "average up". Keeping down spoilage and maintaining a fairly accurate uniformity of case, heat after heat, calls for Containers that not only give long service but behave in a uniform way throughout their entire usefulness.

From every angle that affects either quality or economy, Cast Nichrome Containers average up to the highest satisfaction point. The proof exists in hundreds of modern plants.

All Cast Nichrome Containers are Manufactured under HENDERSON Patents by

DRIVER-HARRIS COMPANY
HARRISON, NEW JERSEY
Chicago - Detroit - Canada - England - France

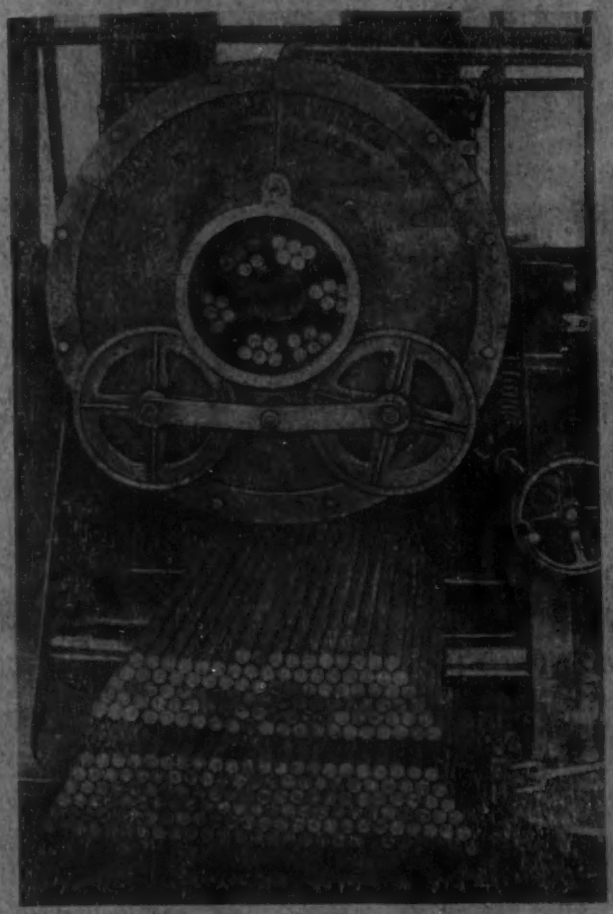


TRADE MARK REG. U. S. PAT. OFF.

Nichrome

CAST **Heat Treating Containers**

Endure in High Temperatures



American Gas Furnaces

Products of more than 40 years' experience and specialization, American Gas Furnaces are made in a wide and practical range of styles and sizes to perform all kinds of heat-treating operations on all classes of work.

The No. 2 B Carbonizing Machine is shown arranged for carbonizing long, cylindrical parts. Several pieces of work are accommodated in each compartment of the fixture in the retort which rotates constantly—permitting quick heating and uniform mixing of work and gas by which all articles become uniformly carbonized to any specified depth in minimum time.

The mine axles shown are 1½" diameter, 50" long and weigh 27 pounds each—30 axles (810 lbs.) being considered a full charge.

Carbonizing Mine Axles—810 Pounds Per Charge

American Gas Furnace Products include:

AUTOMATIC QUENCHING TANKS
BLOWERS
BLOWPIPES OR BLOW-TORCHES, HAND AND STAND
BOOSTERS, GAS
BRASS MELTERS
BRAZING FURNACES AND TABLES
BURNERS
BURNERS FOR ELECTRIC LAMP BULB MANUFACTURE
CARBONIZING MACHINES
CYANIDE FURNACES
CYLINDRICAL FURNACES
FORGES
FORGES, GLASS BENDING
HARDENING HAMMERS
HEATING MACHINES
MELTING FURNACES
MUFFLE FURNACES
OIL TEMPERING FURNACES
OVEN FURNACES
PLATING FURNACES
RIVET HEATERS
SOFT METAL AND LEAD HARDENING FURNACES
SOLDERING IRON HEATERS
SWEEP REDUCING FURNACES
TEMPERING PLATES
TIRE HEATERS
TUBE HEATING FURNACES
EVERY TYPE OF GAS BLAST BURNER, FURNACE AND HEATING MACHINE FOR INDUSTRIAL USES

Tell us your heat-treating requirements and let us prescribe.

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Main Office and Works — ELIZABETH, NEW JERSEY

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¶ Every item in our extensive line of metallurgical testing machines and instruments costs more than the next best device offered for the same purpose.

¶ Take, for instance, any of the Amsler testing machines. A tensile, torsion, impact, or Brinell hardness testing machine produced by Swiss artisans at the famous Amsler works *costs more f. o. b. Switzerland* than machines constructed for the same purpose are being offered f. o. b. this country.

¶ Our photomicrographic outfit for metallography, constructed by the famous Reichert Optical Works of Vienna, *costs more at the Austrian factory* than the next best outfit is being sold for in this country.

¶ And still we encounter no difficulty in placing our expensive apparatus with the many expert metallurgists in this country who INSIST upon "THE BEST".

¶ If the "next best" will do, we cannot be of service.

Are you fully informed on the remarkable features embodied in the Amsler testing machines and in our metallographic equipment? Have you had an opportunity to admire their unsurpassed workmanship?

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Complete Line of Machines and Instruments for Metallurgical Testing and Research Work

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